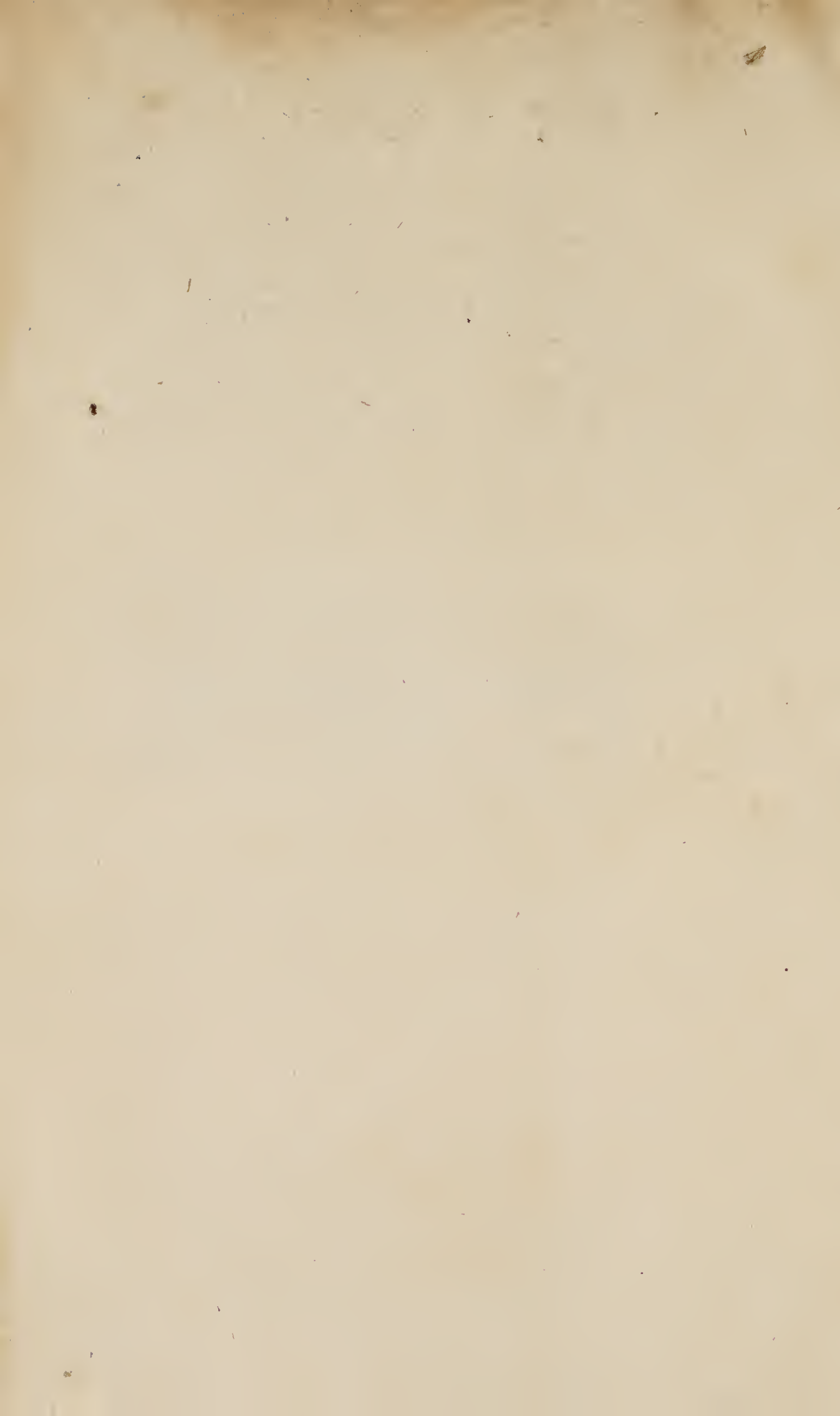


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PEMBERTON, H.

CALGARTH PARK.







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A
C O U R S E
O F
C H E M I S T R Y,

DIVIDED INTO
TWENTY-FOUR LECTURES,

FORMERLY GIVEN BY THE LATE LEARNED
DOCTOR HENRY PEMBERTON,
PROFESSOR OF PHYSIC AT GRESHAM COLLEGE,
FELLOW OF THE ROYAL SOCIETY,
AND OF THAT AT BERLIN,

Now first published from the Author's Manuscript

BY JAMES WILSON, M. D.

L O N D O N,
PRINTED FOR J. NOURSE, BOOKSELLER IN ORDINARY TO
HIS MAJESTY.

MDCCLXXI.



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P R E F A C E.

IN publishing these Chemical Lectures, I shall give some account of their author, in detached particulars, as they occurred to me, during our long acquaintance and friendship.

Doct^r HENRY PEMBERTON was born at London, in 1694, of honest and respectable citizens. He was of a middle stature, fair complexion, and serious aspect. This last did not arise from any gloominess or moroseness in nature; for he was of a mild temper and very free and easy in company; but from frequently meditating on some point of speculation. His senses were acute and delicate, especially that of hearing, whence he received great delight from music, which he indulged by frequenting

quencing some operas and all Handel's oratorios. He early discovered a talent for mechanics, readily performing any manual operation, as making of fire-works, and effecting other contrivances not unbecoming an active and ingenious youth. He was generous, and so far from being envious, that he used to advise and encourage such as fell in his way endued with real genius. Besides he possessed an extraordinary faculty in distinguishing of things; consequently he reasoned always justly, not to be imposed on by a cloud of specious words, and in any dispute he was universally allowed to be in the right. To crown all, his mind was of the best disposition, he having the highest regard for honour and honesty; insomuch that during the very many years I was most intimately acquainted with him, which I esteemed as the greatest felicity of my life, I never knew him to offend against their strictest rules.

In his youth, his health being precarious, he was sent to a country grammar-school at Guildford in Surry; where, from his sagacity and diligence, he readily became master of all
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P R E F A C E. v

the learning, that place could afford. Here he met by accident with books on mathematical subjects, some on the practical parts, others on algebra. Upon these he made very pertinent observations, discovering a surprising degree of invention in those sciences, which he thenceforward cultivated with great success.

Returning to London he read the higher classics with Mr. John Ward, a gentleman perfectly acquainted with whatever related to the knowledge of antiquity, who was afterwards professor of rhetoric many years at Gresham college, and doctor of civil law. His pupil thence received such an impression of the excellency of those writers, that he bestowed much time upon them, and with what success he has given proofs to the public. Now he met with Dr. Halley's fine edition of Apollonius's Conics, rejoicing that so large a volume was written on his beloved subject. This he read over with infinite delight. Nay in the course of his life he had read it over thrice; solving the problem to four lines according to the strictest intent of the ancients, which was

published a long time after in the Philosophical Transactions(a).

As he designed for the profession of medicine, he repaired to Leyden, in order to attend the colleges, as they are there called, of the famous professor Boerhaave.

Here a gentleman lent him sir Isaac Newton's Principia, which was then prodigiously scarce. But great was his surprize, when, contrary to what he had so often heard, he found that book written in a most clear manner; so that he went through it without the least impediment. He no less admired the discoveries made in the optics, and sir Isaac Newton's manner of treating the quadratures. From the introduction to that treatise, he acquired a true idea of the methods of prime and ultimate ratios, and of fluxions, which was afterwards in 1735 published in Mr. Robins's discourse on those subjects. In the enumeration of the lines of the third order he deduced the equations most readily and without any ambages.

(a) Vol. 53. 1763.

Here

Here he met with Dr. Halley's edition of Apollonius de Sectione Rationis, which he could not sufficiently value; as thence he became acquainted with the geometrical analysis of the ancients, which he much valued, and afterwards frequently practised.

He also solved the problem the foreign mathematicians had with some sort of insult proposed to those of England.

His modesty and backwardness of putting himself forwards made him little taken notice of, but an accident procured him much fame. The professor, among other his colleges, gave one upon the subject of vision; here he committed many mistakes in the science of optics: of these our young geometer modestly informed him in a letter. The professor, far from taking this amiss, every where spoke of it with the highest commendation, boasting of his having so great a genius for his pupil, and frequently consulting him about some point in the Newtonian philosophy.

Hence he went to Paris to perfect himself in the practice of anatomy, to which he readily attained as being dexterous in all manual

operations. Now there happened a lucky accident; for the large library of the abbé Gallois was sold by auction. Among other books there was almost a complete set of mathematical ones, both ancient and modern. Hence he furnished himself with good store. In perusing this treasure he chose to begin with originals. Of these he admired Lucas Valerius's (an author now unregarded) determination of the center of gravity in solids. Of this he a long time after informed sir Isaac Newton, who allowed it to be most elegant.

Though Dr. Halley had asserted, that Robert Anderson first shewed how from an eminence to strike an object, yet this is in Torricelli. Among the books there was a tract in 4to, intitled *De novis Spiralibus Exercitationes duæ, &c.* Authore P. Petro Nicolas Tolosæ, 1693. This he read with great pleasure, as the demonstrations proceeded not inelegantly on prime and ultimate ratios. Now he improved Huygen's solution of Alhazen's problems, which was published in Mr. Robins's Remarks on Dr. Smith's Complete System of Optics. Afterwards he per-

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formed

formed what was much more difficult in giving the determinations of that problem(b).

On perusing Regiomontanus, Vieta and other writers on trigonometry, he made several improvements in that useful branch of the mathematics; some of which have been published very many years after in our *Philosophical Transactions* (c).

He also made a collection of curious problems, which he solved by the ancient analysis, intending to write on that most elegant, though neglected subject.

In his return to London, he happened to shew Dr. Keil his solution of the foreigner's problem, with which the doctor was so pleased that he immediately carried its author to sir Isaac Newton, believing the good knight would be glad to find there was so promising a genius. But sir Isaac Newton then took no further notice of our young geometer, which was a great detriment to them both, as after-

(b) In the appendix to the second volume of Mr. Robins's *Mathematical Tracts*, printed in 1761, p. 303.

(c) Vol. 51. part 2d. 1760. Among his papers is a short history of trigonometry from Menelaus to Neper.

wards appeared. This coldness was believed to proceed from some ill offices done by a malevolent person, who then had sir Isaac's ear.

Now he became acquainted with Dr. Mead, to whom he had been before recommended. He also attended very assiduously St. Thomas's Hospital, lodging with a relation, an apothecary, in order to be acquainted with the London practice. Though he thus made himself perfect master of all the branches of physic, he rarely practised it, owing to the fickle state of his health.

In 1719 he returned to Leyden, there to take his doctor's degree. The professor Boerhaave retaining a great esteem for him, obliged him to lodge at his house during his abode in that place. The question maintained in his thesis was, By what power is the eye enabled to discern distinctly objects at different distances. This is determined to be owing to a change made in the chrystalline humours. The demonstrations there used, he afterwards rendered much more elegant, which he intended to publish in another edition.

He

He became still more familiarly acquainted with Dr. Mead, to whom he was greatly assistant in the doctor's writing on the plague, especially in the eighth edition of the book, in which all the objections that had been raised were so thoroughly answered, that no more ever appeared.

The first specimen he gave the public of his skill in what they call the sublime geometry, was by accident. Seeing at a bookseller's shop in one of the *Acta Eruditorum*, a problem proposed as very difficult by Mr. John Bernoulli, he immediately solved it. The solution was published without his name in the *Philosophical Transactions*, No. 372. Ann. 1722, and afterwards amongst the collection of M. Bernoulli's works. But the solving of these kinds of barren problems he looked upon with sir Isaac Newton to be no better than cracking pebbles. Then Mr. professor Smith of Cambridge advertising, that he would reprint Mr. Cotes's *Logometria*, adding other works of that excellent person; Dr. Pemberton in conversation observed to him, that Mr. Cotes had given an indistinct idea of ratios, and what-
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ever may be done by what he calls their measure and that of angles, might be effected by the means of the circle and hyperbola. The professor not only denied this with warmth, but in the preface to Mr. Cotes's works, printed in 1722, admonished the doctor, but without naming him, to lay aside all prejudices, and to consider these things more attentively. Upon this the doctor, in an epistle to me, proved what he had advanced, demonstrated Mr. Cotes's excellent proposition, which the professor had not done, and solved the thirteenth problem of the third book of the *Principia* by a conic section, of which sir Isaac Newton has taken notice in the last edition.

As he desired nothing more than to be acquainted with that great man, he was composing, to bring this about, a treatise giving a familiar account of sir Isaac's discoveries in philosophy. But an unforeseen accident effected this most completely.

Signor Poleni produces an experiment, which, he thinks, establishes beyond contradiction the truth of Mr. Leibnitz's notion of the force of moving bodies. Dr. Pemberton
wrote

wrote a paper containing a full confutation, which Dr. Mead shewed to sir Isaac Newton. The knight was so well pleased with it, that, as great a man as he was, he condescended to visit the doctor at his lodgings, bringing along with him a confutation of his own grounded on other principles. Both these were immediately printed in the *Philosophical Transactions*, No. 373, An. 1722. Hence followed a free intercourse between these two persons, whose conversation turned upon mathematical and philosophical subjects. Sir Isaac Newton was one of the modestest men in the world, so that he even solicited Dr. Mead to prevail on Dr. Pemberton to assist him in making a new edition of the *Principia*.

But in the mean while Dr. Langwith, describing in the *Philosophical Transactions*, No. 375, An. 1723, an appearance in the rainbow not yet taken notice of, Dr. Pemberton accounted for it, and gave by the ancient analysis two solutions relating to the rainbows, the last containing that of a solid problem.

Again Dr. Mead published in 1724 a pompous edition of Cowper's *Muscles*: to this was
pre-

premised a most elaborate dissertation, written by Dr. Pemberton, on the actions of those of the human body. Here was shewn the error Mr. John Bernoulli committed in determining the figure of the cells into which he imagined each fibre of a muscle was divided. Mr. Bernoulli replied, and heedlessly attributed the dissertation itself to Dr. Mead. It contained proofs of the most profound skill in anatomy and geometry; the demonstrations were also grounded on prime and ultimate ratios.

But now the edition of the Principia was entered upon. As the doctor lived a great distance from the author, he mostly sent him letters from time to time, containing observations on the book. These were received with the utmost goodness, and accordingly many alterations were made, more were intended, but prevented for want of time. In particular his friend Dr. Brooke Taylor informed him, there was a mistake in relation to the precession of the equinox, and shewed how to rectify it. Dr. Pemberton for his care was rewarded most nobly, according to the natural generosity of the author, which even old age could not in

the least diminish. But besides, what the doctor still more valued, in the preface he is said to be "*Vir harum rerum peritissimus.*" The omission of the scholium, that mentioned M. Leibnitz, was highly resented by the foreigners; but of this I have spoken elsewhere (d). One author indeed (e) has had the hardiness to insinuate, it was omitted without Newton's consent. Now I am a witness, that he ordered it to be left out, and the new scholium to be substituted in its place, which was intirely composed by sir Isaac Newton, and printed from his own hand-writing.

Dr. Pemberton thought now a proper opportunity offered for publishing his abovementioned treatise, which he begun to read to sir Isaac Newton, who highly approved of it. But he died suddenly; however the book was printed in 1728, by a very numerous subscription, with the title of *A View of Sir Isaac Newton's Philosophy*. In the preface he mentions his connection with that great man, and

(d) In the above-mentioned Appendix, p. 327.

(e) *Histoire des Mathematiques* par M. Montucla, à Paris, 1758, vol. ii. p. 338.

gives his opinion of the mathematical writers for Isaac Newton most esteemed. As that work by the manner of publishing it fell into the hands of great numbers, who could not have the least idea of what it treated on, they expressed themselves dissatisfied with it; but it must be owned, to be an excellent performance, and to answer fully what the author proposed. It has been translated into Italian and French.

He would have published Newton's Treatise on Fluxions, but the owners of the copy asked more money, than the booksellers cared to advance.

Then the doctor advertised he would publish a comment on an English translation of the Principia; and I find in his copy a great number of papers written for that purpose; but a translation very suddenly appearing, hindered him from executing that design. And indeed he began to grow weary of mathematical speculations.

When king George the second visited the university of Cambridge, the doctor had there an honorary degree of doctor in physic conferred upon him.

Being

Being chosen professor of physic at Gresham College, he undertook to give a Course of Chemistry, which was improved every time he exhibited it. This was universally applauded; insomuch that the college of Physicians engaged him to review their Pharmacopœia, in order to make a new edition, purged intirely of every trifle, that had so long disgraced it.

For this purpose a committee was appointed. And the doctor made experiments on the prescriptions, and drew up two plans, containing reasons for the intended alterations. Accordingly the Pharmacopœia corrected came forth. The college not doubting but it would be put into English, desired the doctor to undertake that task. This he performed, premising a narrative, and adding remarks on most of the prescriptions, being the substance of the plans he had laid before the college. Hence it appeared, how well he was acquainted with pharmacy, and how mean an opinion he had entertained of most of the writers on that subject.

I mentioned the doctor's readiness to assist any one of parts. How he behaved to Mr. Robins I have largely declared in the preface to the latter's Mathematical Tracts.

About the same time was recommended to the doctor a young gentleman, Mr. Glover, just come from school. As he was indued with a disposition and capacity to succeed in any kind of study whatever, the doctor advised that of the mathematics, informing him of the most genuine authors; and also to perfect himself in Greek. The branches of the mathematics proper for a gentleman to know he readily learnt, with thoroughly comprehending their nature, and perceiving the force of the manner of reasoning used in those sciences; in time he rendered himself master of the Greek, and of the authors written in that copious language. But Mr. Glover possessed besides an extraordinary talent for poetry, and from verses he had early composed, was formed the admirable poem of Leonidas. This being published in 1738 (f), the doctor, who

(f) In 1770 came out a fifth edition augmented.

entertained particular notions about this subject, took an opportunity of printing them in a pamphlet, (g) intitled *Observations on Poetry, especially the Epic, occasioned by the late Poem upon Leonidas*. This shewed the great judgment and learning of the author, and it was received by the public with singular approbation, no objection having been ever made to what was there advanced. Abroad a writer of a literary journal having given an account of the doctor's pamphlet adds, "*Ceterum auctor de epico et tragico carminis genere rationem ducem fideliter secutus est* (h)."

The poem of *Leonidas* procured Mr. Glover to be a great favourite with lord Cobham, and consequently to be well known to his lordship's nephews and their acquaintances. To these Mr. Glover recommended Dr. Pemberton, whom they honoured by bespeaking and attending a course of his chemistry. As these were the patriots of the times, the doctor, having thoroughly considered the writings of

(g) The author has left a copy with additions.

(h) *Nova Acta Eruditorum*, Octob. 1747, p. 598.

xx P R E F A C E.

Machiavel, Harrington, Nevil and others, drew up a plan of a free state with a king at the head. This was much admired by such as had read it; and many years after his friend Dr. Brocklesby presented a copy to the late right honourable Charles Townsend chancellor of the exchequer, who so well approved of it and its author, as to espouse his cause when the city thought fit to demolish Gresham college; but I do not find a copy of it among his papers.

Mr. West being about publishing his Translations of Pindar, the doctor presented him with a succinct account of the ancient ode, which was printed in the preface, where the author styles him his learned and ingenious friend.

Though he had discontinued all mathematical pursuits, yet he was drawn on Mr. Robins's account into a controversy about fluxions. But of that I have spoken in another place (i).

For many years past he had accustomed himself to ride with some agreeable friend

(i) In the above-mentioned Appendix.

every summer for his health's sake over different parts of the kingdom. Here he took an opportunity of visiting our mines and the shops of our workmen, as appears from his *Course of Chemistry*.

During the neglect of mathematical studies, he used to amuse himself with composing on various subjects; for he never could be idle, whilst he enjoyed any tolerable degree of health. On our attempts to alter the style, he wrote a learned dissertation on that affair. But in my opinion much need not be said on a thing so obvious. The beginning of the year should be on the shortest day, but it being now fixt, it must stand as at present. Clavius has defined exactly enough its length. The consideration of the moon ought to be intirely laid aside, as its motion and that of the sun are incommensurable, and therefore never can agree. Besides here the moon is quite useless, having no relation to the seasons. It was at first introduced through mere ignorance, and continued through superstition. The moveable feasts, we make to depend on its motions, may be properly fixt in some part of those months, which they seem originally

ginally designed to occupy. Again a project was offered for reducing our weights and measures to the same standard throughout the nation. Accordingly a committee was appointed, and a long narrative published for this purpose. But it abounded with so many mistakes and absurdities, that the doctor was prevailed on to write on the subject. This being a very intricate affair took up much time; and I believe he never perfectly finished what he intended.

On his present majesty's accession to the crown, Samuel Martin, esquire, procured the doctor a pension, and that in the genteelest manner, without giving him before-hand the least hint of any such design. Mr. Martin had been one of the doctor's travelling companions, and well acquainted with his merit.

Now he very much contracted his acquaintance. Dr. Letherland, who possessed so fine a taste in geometry and polite learning, and Matthew Raper, esquire, were of ancient standing; but the first was dead, and the other resided generally at his seat in the country. So the doctor confined his constant visits to his beloved niece's family, Mr. Glover and his friends,

friends, together with some worthy merchants in the neighbourhood, where the time was passed most agreeably on all sides.

But some years before, being attacked with a violent fever, which terminated in a defluxion on the leg, whilst he was under the surgeon's care, his inclination for the mathematics revived, and he composed a dissertation on eclipses, which had like to have been published in the Philosophical Transactions, but was prevented by an accident.

He began to print several dissertations on mathematical subjects. One was on the Loci Plani; the rest I have already mentioned. He would have gone on so to do, had he not been prevented by death; he was preparing for the press a solution of all the cases with their determinations of the ancient problem de inclinationibus, which was a performance of his youth.

But in 1770 he was seized on by a most violent distemper, which, his friend Dr. Reeve thought, proceeded from an obstruction in the gall-bladder, and indeed the patient was covered all over with a jaundice hue. Out of

this he unexpectedly recovered; the yellowness intirely disappeared, and he seemed thenceforward to be more hearty and of better spirits than ever. However, in March, 1771, he was attacked by the same distemper, which carried him off in two days time, to the grief of all who had been happy in his acquaintance.

His fortune, which was considerable, he left to a very worthy gentleman, Mr. Henry Mills, who is married to his niece, by which amiable person he has issue two sons, both of age, in perfect health and strength, very sober and diligent in business.

Among his papers were many mathematical ones; as demonstrations of the spherics and spherical projections, enow to compose a treatise on those subjects; a dissertation on Archimedes's skrew; improvements in gageing; to find in a given latitude the point that ascends the slowest of any in the ecliptic; to find in the ecliptic an arch of a given length, which will be longer in rising than any other arch of the same length; to find when the oblique ascension differs most from the arch to which it belongs; the principles of Mercator's and mid-

dle latitude sailing ; to find the heliacal rising of a star ; to compute the moon's parallax ; to determine the course of a comet through a parabolical orbit ; with others, all most elegantly performed.

The Course of Chemistry he intended to improve by making farther experiments, and to change its form ; which caused him never to publish it in his life-time. But he was by various accidents prevented from prosecuting his purpose. However, though it wants the advantages it might have received, I now print it from the original manuscript, believing, that all lovers of the art will be pleased to find here its operations explained on genuine principles.

As he used to deliver out schemes containing an account of the design and the contents of his courses, I have here printed one of them, altered in some things, in order to accommodate it to the last review he made of his lectures.

JAMES WILSON.

London,
August 10, 1771.

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S C H E M E
FOR A
COURSE of CHEMISTRY.

THE design of this Course is to explain both the practical and philosophical part of chemistry.

IN relation to the first will be exhibited the preparation of all the chemical medicines in present use, with an explanation in particular of the regulations now established by the college of physicians in their new dispensatory: also the smelting, refining, and such like processes on metals; together with other operations in those trades, or employments, which depend upon the principles of chemistry.

IN all these it is proposed to describe in the plainest and fullest manner the method of proceeding in each operation, and to deliver the cautions necessary to be observed in them.

WITH regard to the philosophical part of chemistry, the practical processes are disposed in
such

such an order, as may be most conducive towards shewing the reason, and true effects of each operation; and such others are added, as are requisite for explaining the discoveries, which have hitherto been made in nature by chemistry, besides some attempts towards farther advances.

IN the progress of these experiments will be given an account of the essential difference between animal, vegetable and mineral substances; of the nature of nutrition, vinous fermentation, and putrefaction; of the nature and different operation of menstruums, wherewith bodies are dissolved; of the nature and operations of the air, how aqueous vapours and clouds are suspended in it, by what means it causes bodies to burn; and why it is preyed upon by them in burning; how air is generated in fermentations and distillations.

In general it will be shewn to what principle bodies owe the conservation of their distinct forms, and what powers procure those changes, whereby the face of nature is perpetually varied and renewed.

THE subject of each lecture follows.

P A R T I.

Of chemistry, and its operations in general.

LECTURE I. p. I.

THE threefold design of chemistry; the production of metals, the improvement of medicine, and of natural philosophy. The rise, and progress of the art.

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LECTURE II. p. 16.

THE nature of heat explained upon sir Isaac Newton's principles, and the doctrine confirmed by experiment.

LECTURE III. p. 37.

OF chemical operations, and the requisite instruments in general. The division of the operations of chemistry into analysis and composition. Concerning volatility and fixity, and the difference between distillation and sublimation, with the instruments of each. The instruments for melting and calcining. Of digestion, and its instruments. Of lutes and hermetical sealing, with the method of cutting off the superfluous parts from glasses. The various kinds of heat; that of water, of sand, the open fire, and the two kinds of the reverberatory fire, with the furnaces for each of these heats: also the blast and wind furnaces; as likewise the athanor for continuing an equable degree of heat any length of time without intermission, and with small attendance; also Vigani's ex tempore furnaces composed of loose bricks only, to be set up and taken down at pleasure, wherewith all the operations of chemistry may be commodiously performed by those, who have not a fixt laboratory. Of the several sorts of fuel. Of clays and bricks, particularly Windsor loam, and the Stourbridge clay. Of the several sorts of weights.

LECTURE IV. p. 63.

OF chemical analysis in general. The chemical principles produced by the analysis of bodies enumerated. In particular of water; why it dilates in freezing; experiments with freezing mixtures, and the cause of their operation considered. Of salts and spirits; the acid, alkaline, and neutral; the criterions, whereby to distinguish acids and alkalis. Of oils, and their inflammability: burning considered, with the office of the air in it illustrated by experiment; also why water extinguishes fire. Of earth, the fifth principle. Of the aerial vapour separated from bodies by distillation.

LECTURE V. p. 82.

OF chemical composition in general. Of menstruums; their action explained; why heat promotes it; experiments on the heat and cold produced in mixtures and dissolutions, and the cause thereof considered: concerning precipitation and crystallization. Why salts shoot in different figures.

P A R T II.

Of animal and vegetable substances.

LECTURE VI. p. 95.

ANIMAL and vegetable substances analyzed by distillation; whereby all of the animal, and some of the vegetable are shewn to produce an
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alkaline spirit, and salt, besides an oil ; the rest of the vegetables containing an acid spirit with an oil ; all leaving a black coal to be farther examined hereafter. Milk and urine considered particularly, and experiments made with the phosphorus of urine. Charcoal how made. The aerial vapour collected.

LECTURE VII. p. 106.

THE purification and farther analysis of the salts, spirits, and oils of the preceding lecture. How oils are separated from watry liquors. The distillation of the natural balsams exemplified in turpentine ; whence rosin, both yellow and black : how turpentine is gathered, and how tar and pitch are made. The distillation of essential oils : why these oils and resins rise so freely, while other oils lighter than several of these can be obtained only by expression. The sublimation of benjamin and camphire.

LECTURE VIII. p. 122.

THE aerial vapour arising from animal and vegetable substances in distillation farther considered. The effects of burning animal and vegetable substances in the open air : the fixt alkaline salt of vegetables prepared ; Tachenius's method ; how pot-ashes and pearl-ashes are made : foot distilled. Reflections on what hath preceded.

LECTURE IX. p. 136.

ON fermentation and putrefaction. What relation sweetness bears to vegetable fermentation; here sugar distilled: fermentation described in its whole progress to the making first of beer and wine, then of vinegar; and the nature of this operation inquired into: the inflammable spirit distilled from wine, and farther purified; of rectified and proof spirits, with the method of examining the standard of spirits: vinegar also distilled: the original of tartar, and other essential salts; the purification and distillation of tartar; cream and crystals of tartar. How fermentation may be stopt or promoted. The effects of putrefaction; whence animal digestion explained.

LECTURE X. p. 154.

COMPOSITIONS from the productions of the preceding analysis considered; and the first of the compositions by the spirits and salts: here fixt alkaline salt run per deliquium, as it has been commonly stiled: also spirit of wine rectified by these salts. These salts fermented both with the acid of vinegar, and of tartar; whence the sal diureticus of the present dispensatory, and tartarum solubile. The effects of the acid of vinegar on coral, and the like terrestrious substances. Magistrum and salt of coral.

LECTURE XI. p. 161.

COMPOSITIONS by the means of oils and vinous spirits. Soaps a composition of oils with fixt alkaline

kaline salts : soap of tartar : why these salts cause a sudden separation of the volatile salt from fresh urine. The tincture received by spirit of wine from these alkaline salts considered. The solution of essential oils and volatile resins by spirit of wine : tinctures drawn from vegetables by wine and its spirit ; here extracts and resins.

P A R T III.

Of FOSSILS.

LECTURE XII. p. 169.

OF the fossil and similar salts ; of sea-salt, nitre or salt-petre, alum, vitriol, and borax ; their crystallization. These salts considered particularly. Their distillation, and rectification of their acid spirits. The calcination of vitriol. Its oil. Glauber's sal mirabile. A false tartarum vitriolatum. Aqua regia and fortis. The dying of scarlet. Why Glauber's spirit of sea-salt and of nitre smoke incessantly ; and why acid of vitriol exposed to the air increases in bulk. Here occasionally how vapours are raised, and why condensed into clouds. How each of the fossil salts is obtained originally.

LECTURE XIII. p. 187.

SALTS farther considered. The effects of the acid spirits of the preceding lecture on one another, and on other bodies : these acid spirits fermented with the fixt alkaline salt of vegetables,
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and

and what salts are thence produced ; here tartarum vitriolatum : the like experiments with the volatile alkali ; here the composition of sal ammoniac, with its sublimation : the earthy part of all these salts, except nitre, precipitated by alkaline salts ; whence some light into the nature of nitre : the fixt alkali more powerful than the volatile ; hence the decomposition of sal ammoniac by a fixt alkaline salt, the spirit of sal ammoniac. The purification of animal salts by spirit of sea-salt, and salia volatilia oleosa. The nature of the pigments made with alum : the Prussian blue here prepared, and shewn why a large quantity of this coloured terrestrious substance is produced from two transparent liquors : the use of alum in dying. The detonation of nitre. Nitre increases the inflammability of bodies. The effects of the phosphori explained, and what part of the air aids the burning of bodies. The acid spirits dispossessing one another ; the acid spirits dulcified by spirit of wine. The spiritus vini ætherius introduced by Frobenius. Here explained why spirit of wine restrains the fermentation of vinous liquors. Why the serum of the blood and whites of eggs are coagulated by heat, and the difference between the fat of animals and the oils of vegetables considered. The effects of the acid spirits on oils and camphire.

LECTURE XIV. p. 201.

OF mineral sulphurs. Whence common brimstone obtained. Here the general definition

tion of spars; and of mundics, otherwise called pyrites or marcasites. Common brimstone decomposed; whence spiritus sulphuris per campanam, and the aqua sulphurata of the present pharmacopœia: why the smoke of brimstone checks vegetable fermentation: how bitumina differ from sulphur: sulphur not to be analyzed by simple heat, subliming intire into flowers: sulphur dissolved in oils, and by the help of fixt alkaline salts in water: here the balsama sulphuris, and hepar sulphuris. Magisterium sulphuris. Sulphur fulminated with nitre; whence sal prunellæ, and sal polychrestus; the composition of gun-powder. The use of corning gun-powder. Pulvis fulminans. The general structure of rockets, bombs, granadoes, and other fire-works, with the reason of their effects. Homberg's phosphorus made. Orpiment here considered, and that ambiguous substance amber.

LECTURE XV. p. 216.

ON stones. Gems. What stones will make glass, and how the operation is performed; why glass, when melted, is wrought by blowing, whereas melted metals are cast in a mold. On lime: plaister of Paris. Phosphorus of alum accounted for: aqua calcis: the acrimony of fixt alkaline salts, improved by lime into a caustic; whence lapis infernalis and the other common caustics in surgery: the action of lime on sal ammoniac, whence spiritus salis ammoniaci cum calce. Mr. Boyle's fuming liquor with

fulphur, lime, and sal ammoniac : sympathetic ink with lime and orpiment. The use of lime in making soap ; here soap, both hard and soft, prepared : the use also of lime in making and refining sugar : fulphur dissolved by lime, whence fulphur precipitatum, commonly called lac sulphuris. The phosphorus of Balduinus described.

P A R T IV.

M E T A L L U R G Y.

LECTURE XVI. p. 231.

GENERAL character of metals, perfect and imperfect. The calcination of the metals. How lead, tin, copper, iron, and quicksilver are calcined by our fires ; whence from lead minium. Silver and gold not reducible to a calx but by burning-glasses. From quicksilver mercurius calcinatus, usually called precipitatus per se ; also from lead, litharge. From lead and tin together the powder called putty, wherewith metals are polished ; how this differs from the putty of the glaziers. Lead is used in plasters. From iron, crocus martis aperiens ; from lead, vitrum saturni and flint-glass. The manner of glazing earthen wares here described. The particular phænomena in the calcining of metals by the burning-glass. How calcined metals may be restored. Spelter shewn to flame upon melting. The cause of calcination, and of such restitution.

LECTURE XVII. p. 249.

THE action of the acid spirits upon metals. Those of nitre and sea-salt suffice for dissolving all metals. These spirits sometimes corrode the metals into powder only, sometimes dissolve and convert them into a salt capable of crystallization, whence the lunar caustic. The precipitation of dissolved metals, hence aurum fulminans, mercurius precipitatus albus. How gold is refined from silver. By oil of vitriol dissolving iron, is made sal martis; by corroding quicksilver, turbith mineral. Hence also vitriol of iron, and oleum martis per deliquium. Tin dissolved in vinegar produces sal jovis. From lead and vinegar, saccharum saturni. The making cerusse. From copper and vinegar, verdigreese. From spirit of nitre and quicksilver, mercurius precipitatus ruber and arcanum corrolinum. Filings of iron and tartar produce chalybs tartarificatus and Helvetius's styptic. The action of these acid spirits on the imperfect metals, whence magisterium bismuthi.

LECTURE XVIII. p. 260.

THE action of solid salts upon metals. Here mercurius sublimatus corrosivus, its use in refining gold. Mr. Boyle's perpetually fuming liquor. Mercurius dulcis. The causticum antimoniale, known by the name of butter of antimony, cinnabaris antimonii, oleum antimonii, mercurius vitæ, diaphoretic antimony, bezoar mineral, and the bezoardic spirit of nitre. From sal ammoniac, flores salis ammoniaci martiales,

or ens veneris, so called ; aurum musivum or mosaicum. Here also the corrosion of the metals by sulphur ; whence factitious cinnabar, and chalybs cum sulphure preparatus.

LECTURE XIX. p. 270.

THE separation of metals from their ores, and the reasons of the several operations used for this end. Of the gold and silver ores of America, of the gold sands of Africa, and how the metal is there collected : how the same metals are obtained in Europe : how lead, tin, copper, and iron are separated from their ores by charcoal ; and how lead, tin, and copper are separated by pit-coal. How the refiners melt, what they call the sweep. The several ores shewn, and also models of the several smelting-furnaces.

LECTURE XX. p. 285.

OF assaying, with the nature of the several kinds of flux-powders. Assays of the metallic ores performed.

LECTURE XXI. p. 294.

THE separation of the imperfect metals from their ores. The separation of quicksilver from its ore, in particular from native cinnabar. How bismuth is melted from its ore. How spelter is produced. Bath metal. The production of antimony, and operations on it ; the glass of antimony, the calx commonly called diaphoretic antimony ; reduced to the metallic form named regulus

gulus of antimony, crocus antimonii, regulus stellatus, and vinum emeticum. The antimonial cup. From the scorixæ, the golden oil of antimony. Gold purified by antimony. On arsenic, zaphor, and smalt. On the mineral called black lead.

LECTURE XXII. p. 304.

OF refining, separating, and other preparations of metals. How gold and silver, are separated from lead, and how refined by this means. Why melted glass sticks to iron, though to no other metal. Litharge made. How the separation of metals is performed at the mines, how by the refiners, and how in essays. How silver is got from lead, how separated from copper so as to preserve both metals.

LECTURE XXIII. p. 312.

EXPERIMENTS and other operations on metals. Brass and steel made. Steel hardened and tempered. Why silver and gold are alloyed : an account of our present standard, with the changes it has undergone. Other mixtures ; whence bell-metal ; cannon-metal ; the metal of organ-pipes ; pot-metal ; bronzes of all kinds ; Bath metal ; pewter ; folders of all sorts, and by what artifice folders are made to join to the metals ; how iron and copper are tinned, and how silver wire is gilt ; amalgamas ; how glasses are foiled with quicksilver, and how water-gilding is performed.

LEC-

LECTURE XXIV. P. 331.

THE CONCLUSION.

GENERAL recapitulation with additional experiments. Here considered the two universal active principles in nature, the repulsive and attractive, and shewn that the first is owing to sulphur, and the other to the acid in bodies : and consequently, that the acid principle unites the parts of bodies, and preserves to each its respective form, unless an external acid is applied to the body under circumstances, whereby the body is broken, and a new compound succeeds. The nature of the air farther explained : that the air causes bodies to burn by the same principle as acid spirits corrode metals and other terrestrious substances.

THE lecture concludes with some observations on the changes in the taste of bodies, on colours, and with an explanation of the nature of mineral waters.

A
COURSE of CHEMISTRY.

P A R T I.

L E C T U R E I.

*Of the Rise of Chemistry, and its Application to
Medicine.*

THE operations in the galenical pharmacy are few and simple; but the chemical are more complex, requiring a greater variety, and a more artificial structure of instruments for its several processes.

In treating of this part of pharmacy, it is not only necessary to describe the operations, but to explain the principles upon which they proceed, and the philosophical deductions which may be made from them; for chemistry has not only
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been cultivated by physicians, as adding to the stock of the more ancient medicaments, but for the insight it affords into the constitution of natural bodies; whereby it promises no small improvement of the physiological branch of medicine, by leading to a farther knowledge of the nature of our blood and humours, than could otherwise be obtained.

But, previous to the treating of both these cases of chemistry, it will be requisite to give some general idea of the art, and whence it first took its rise.

That all sensible bodies are composed of many different parts is evident, because they can be broke to pieces, and divided into very minute fragments, by the instruments of artificers. Accordingly, all mechanic performances consist in dividing, re-uniting, and varying the forms of bodies: nay, the operations of nature, by which all things subsist, through the alternate destruction and renovation of natural bodies, seem to be only a continual separating and re-composing the parts of matter, by the means of certain powers of nature fitted to that end.

Chemistry, according to the extent at present assigned to the art, is an artificial application of these natural powers, whereby to discover the nature of these powers, and in what manner they
act ;

act; as likewise, by the changes thus wrought on bodies, to find out their make and constitution, and also to form new productions useful in human life.

The two great branches of this last, which is the practical part of chemistry, are the preparing of medicines, and the treatment of metals.

In regard to the antiquity of each of these, I do not know, that the application of chemistry to physic can be traced higher than the learned times of the Arabians. In general, many of the present forms, under which medicines are usually administered, we owe to them; and to this day, retain many words in pharmacy derived from their language; such as, syrup, julep, lohoch, and the like, which are originally Arabic words.

Among the preparations of pharmacy in general, some only mix the medicine with such other substances as may preserve it from corruption, so that it may be kept a longer time fit for use; the intention of some is no more than to cover over and disguise the taste of such medicines as are disagreeable to the palate; but others separate a part from the gross material, whereby the medical part of the material being disunited from the rest, it may not only be taken with less reluctance, but may operate more forcibly, than when united with the rest of the com-

pound : moreover, the effect of such separated parts is oft times very different from the effect of the compound itself.

Decoctions in water are preparations where the juices are separated from the gross parts of the medicine by boiling ; and this preparation has been in use from the earliest times : but, besides this simple method of separating the effectual from the inefficacious parts, the Arabians introduced other more artificial kinds of separation, for this purpose, by chemical operations.

The other branch of practical chemistry, which consists in the smelting and refining of metals, has been in use from the earliest accounts of time. Indeed, this is an art so necessary, that, till it was discovered, men could not have led any other than a savage life.

Though both these subjects are at present considered as the proper objects of chemistry, yet it must be confessed, that the art was very different in its original. The name of chemistry seems first to have made its appearance in the world with the ridiculous pretence of converting other substances into gold and silver. How ancient this fanciful scheme has been, or where it first took its rise, is not easy to determine. It certainly owes not its original to the Arabians ; for it was undoubtedly among the Greeks some
ages

ages before they had any communication with that people. The name of the art occurs in Julius Firmicus, an author near the time of Constantine the Great; and within an age or two after, the scheme itself of making gold and silver, is mentioned, by other authors, as openly pretended to. And, on the other hand, Abul Farajius, an eastern writer, assures us, that, as the wandering Arabs were always destitute of arts, so those who lived in fixed habitations, had no other subjects of literature among them, before the times of Mahometanism, than the study of their language, and poetry; they made no pretensions to any subject of philosophy whatever, not even astronomy; though, for the use of agriculture, they were obliged to observe the risings and settings of stars; yet in this they confined themselves merely to practical observations, without attempting to raise any astronomical system upon them. Now, the earliest writers upon this art of gold-making always give themselves the name of philosophers in so high a strain, as if they only were worthy of that appellation: they likewise speak of their art, as of very great antiquity; but we have no writers upon it, that can with any reason be supposed prior to the translation of the Roman empire from Italy to Constantinople; though there are

found, in some of the libraries of Europe, pieces with very ancient names prefixed, such as of Democritus, and the still much more ancient Ægyptian, Hermes. This has made some moderns fond of imagining the art to have been in Egypt from the earliest times : but these are credulous gentlemen, and proceed upon the supposition, that this piece of skill did really once exist ; that the immense wealth those people boasted of to strangers, was produced by this art ; and even give ear to the tale, that Dioclesian, to hold, at last, this nation in subjection, was obliged to destroy their books of chemistry, in order to cut off a source of wealth, by which they were instigated and enabled continually to rebel ; whereas it is extremely incredible, that so much as a pretence of this kind could have existed among that people, and not have come to the knowledge of the Greeks, while they were masters of that country, however industriously the secret might have been concealed. If, therefore, this imaginary art did not take its first rise among the Greeks, in the latter times of the empire, when learning and knowledge declined, as most probably it did not, I think we must look out for some other source whence to derive it. Travellers inform us, that this scheme has, for some ages at least, been
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been pursued with assiduity by many of the people of the East; and the Romans began to have communication with the Persians even before the removal of the empire eastward, which, upon that nearer approach to them, must have increased: by this means, therefore, they might become acquainted with this, and perhaps other fooleries of the eastern nations, with which, in the decline of arts, they themselves were captivated.

It does not appear, that the application of any chemical productions to medicine was attempted thus early; but the Arabians expressly applied chemical operations to this purpose. Though the absurd conceit of discovering, by the secrets of this art, one medicine that should be a universal remedy against all diseases whatever, is of a more modern date. If Paracelsus is not the first, he is the most eminent of the pretenders to this incredible secret; to which Van Helmont has added the farther extravagance of an antidote even against fate, and promises no less than immortality itself.

The first of these, Paracelsus, whom every true adept admires to this day, appeared at the time of that grand restoration of arts and learning, when science began to be delivered from the shackles put on the pursuit of knowledge

by the superstitious veneration for antiquity, which, till then, had been an effectual bar against improvements of any kind. At this time arose Vesalius, by whose labours in anatomy, the dictates of the ancient sages were brought to a just trial, whereby the formal doctrines of the schools, built on Aristotle and Galen, were found not so infallible as had hitherto been presumed; and from hence a genuine method of inquiring into nature was gradually introduced. At this time, Paracelsus also entered the lists, and declared open war upon the schools, disavowing, in the most opprobrious terms, the whole ancient doctrine, and the philosophic systems, by which these ostentatious superfluities were supported, to which all men had as yet implicitly subscribed. But nothing more rational, that should prevail with men to quit the dictates they had embraced from their earliest youth, could be expected from one of this man's character, which was perhaps the most absurd that ever imposed on mankind. From the age of five and twenty, his life was spent in drunken debaucheries with the most illiterate people*; his whole pretensions in physic supported by a daring and inconsiderate use, after the manner of more modern empirics, of some powerful medicines, (though, perhaps,

* Oporin. Epist. ad Solenandr. et Wier.

much fewer in number than is commonly pretended) in which it must be supposed he was sometimes fortunate; but probably much oftner unsuccessful, if he scrupled not to own to Oporinus, his admirer and follower, that he scarce ever could keep his practice in credit, above a year in any one place†. What kind of reformation he aimed at, may be judged of by the following specimen, where, in censuring the doctrine then in fashion, of appointing directors to guide medicines to the diseased part, he explains the matter thus: *Non enim eo modo medicina provehitur, sed seipsam promovet per virtutem suæ imaginis.** For example, eyebright has in itself the form and image of the eye: whence, when it is taken in, it passes to, and stops at its own member, and with the form of that member; so that the eyebright becomes entirely eye. In like manner, is contained the form of all the members of the human body in plants, stones, metals, and minerals.

Thus, though from this time the sciences in general began to be cultivated in a more rational manner than before, chemistry did not advance by the same degrees with the rest, from its

† Conring. de Hermetic. Medicin. l. ii. c. 13. ex Oporin. Epist.

* Labyrinth. Med. c. 8.

professors inlisting themselves under this mad-man, and rendering themselves ridiculous by labouring in earnest to find a meaning to such drunken ravings, and professing a veneration for one, who could assert the spleen, and even the kidneys, to be parts noxious to life, and ought to be destroyed; nay, could treat the idle tale of Fortunatus and his wishing-cap, as composed by good and holy men.

But, indeed, it has been the fate of chemistry to be, for a long time, chiefly cultivated by men so far removed from that sobriety of mind and judgment necessary both in philosophical and medicinal enquiries, that they have rather rivalled each other in extravagancies, he being most admired, who abounded in conceits the farthest removed from good sense. Of this no greater proof can be given than in Van Helmont, who advanced himself to become a dangerous rival in fame even to the great Paracelsus, by those dreams, and doting fancies, with which, in obscurity, he amused his rambling imagination, that render him no less an object of contempt, than the supercilious ignorance of the other merits our scorn and indignation.

These men's absurdities, as well as the ridiculous original of the art, would naturally prejudice men of understanding against it; but as it
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has at length been also cultivated by men of more sober minds, it has surmounted these prejudices; and being found to have actually supplied us with many valuable remedies, a just distinction has been made between the art itself, and the follies of its professors; and such chemical preparations as are found to have real use in physic, are universally held in due esteem, without being either extravagantly extolled by one set of men, or unreasonably depreciated by another.

The pursuit after the philosopher's stone, or the art of making gold, and the search after the universal medicine, are now distinguished from the more vulgar part of chemistry by the name of alchemy; and it is highly proper, that such extravagancies should be effectually distinguished from what is useful, that while one is treated with the contempt it deserves, the other may not lose its esteem in the minds of men.

But besides the two uses of chemistry already mentioned, that of preparing medicines for the use of physic, and that other, which relates to the metallurgic art, there is also a third purpose to which it has been applied; which is the improvement of natural philosophy, and by its operations to gain a further insight into the constitution of natural bodies. For this design, chemistry

mistry is abundantly fitted ; for there is no way so obvious of coming at the knowledge of the structure of bodies, as by dividing them, and separating the parts of which they are composed, so that each part may be viewed and considered separately.

The first enquiry to be made into organical bodies, such as animals and vegetables, is by taking to pieces the organs of which they are composed, and to consider the several uses of each. Thus great progress has been made in the knowledge of animals by anatomy ; and also a great insight gained into the structure of vegetables from such inquiries into their composition, as, from its similitude to what is done in the anatomy of animals, is usually called the anatomy of plants.

Thus is found, by what organs animals and vegetables are rendered fit to continue on their respective lives : but how the parts of matter, which frame these organs, are constituted and held together, is no part of this anatomy to teach ; this is still a more remote enquiry ; and in this chemistry promises no small assistance.

But it is not to be expected, that the fore-mentioned extravagant writers, whose thoughts were carried astray after those wild pursuits, of the making of gold and universal medicines, should
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be able to make any sound discoveries in natural philosophy : in fact, it appears, that, though they are very bold in their pretensions, they are here also consistent with themselves, and have indulged the like idle dreams in their inquiries into natural causes.

This use of chemistry our countryman, Mr. Boyle, has cultivated in a manner that has done him and the art honour. He, at the same time that he practised in the art with great assiduity, has censured and confuted the vain reasoning of preceding chemists with much freedom.

But above all, the immortal Sir Isaac Newton must here be mentioned, of whom it appears, from his writings, that the art of chemistry was worthy a considerable place in his thoughts, and that he was very well acquainted with its operations. Nor did he cultivate it without some measure of the like success, as he had in all the other subjects that employed his mind. He has given hints that, well improved, will open a way to make the greatest discoveries in nature, by the means of this art. Not only his general proofs, drawn from chemical experiments, of some active principles existing in nature, by which all natural effects are caused ; but his more particular thoughts, concerning the nature of acids, cannot be sufficiently admired. If we do not
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rest satisfied in expatiating upon these general hints he has given us, but make that use of them, he intended, and consider them as guides to a more particular discovery of the nature and manner of operation of these powers, I doubt not, but at length some happy genius will arise, who shall open to our view a new and large field of discoveries. This I am the more emboldened to say, when I consider the discoveries this great man has himself made, not only in the larger system of the world, but also concerning the operations of nature in the small parts of matter. And as this latter part of his discoveries are made by the consideration of light, and the mutual action between it and bodies; so we are to take notice, that the operations of chemistry are principally produced by the application of heat, which is the great instrument that nature herself makes use of in all her operations, and appears always to accompany light in proportion to its quantity. And what should farther raise our expectations from experiments made by the application of heat and fire is, that heat is such a universal instrument of nature, that the light of the sun, by which all nature lives, sheds its vivifying influence by its power of producing heat.

As I design to pursue this Course of Chemistry in the method I judge most conducive to illustrate

trate the application of this art to natural philosophy, I shall begin with explaining, as distinctly as I can, the nature of heat; for, since the operations of chemistry are produced chiefly by heat, in order to judge of the changes wrought in bodies by chemical operations, it is necessary to know how heat operates, and what effects, in general, it is disposed to produce in the subjects, whereon it acts: and this I design for the subject of our next meeting.

LECTURE II.

I Proposed, at the last meeting, to open our chemical processes with some considerations on the nature of heat.

The most conspicuous cause of heat is the sun; without whose beams, a universal cold would overspread the face of nature; all motion and life would cease; and the whole earth, with all things it contains, would become one dead mass of matter: but the sun, being also the great parent of light, it has been usual to speak of light and heat promiscuously, as if the immediate instrument of both were the same. However, it must be acknowledged, that they do not accompany each other constantly in the same proportion. I admit, that heat always follows light; and that the degree of this heat is proportional to the quantity of light: for though it is certain, that we often see light, where we feel no sensible heat at all, (such a light is the shining of the glow-worm, of rotten wood, of the foam of the sea, of the phosphorus, and the like) yet it must not be concluded, that these weak lights do not give a proportional heat, though it be insen-

sible to us; for our organ of sight is to be affected by a very small quantity of light. The light of the moon is greatly more sensible than any of these; and yet its quantity, upon computation, will be found to be exceeding small.

The light of the moon is the rays of the sun reflected from that planet to us; and what part of the sun's light the moon receives, and how much the light reflected from the moon is scattered before it comes to us, may be computed without difficulty.

By this means might be compared the light we receive from the sun with that we receive from the moon, if the moon reflected all the rays of the sun which fall upon it; for then the greatest light we can receive from the moon, when at the full, and also nearest to the earth, will be exceeded by the light of the sun more than 87,000 times. But if we suppose the moon to reflect but half the light that falls upon its surface (which is the most that can with any probability be supposed), then the light of the moon will be exceeded by the sun's light more than 170,000 times; and in the mean distance of the moon from the earth, her light will be exceeded by the sun more than 190,000 times. Some experiments have concluded it to be scarce two thirds of this.

Now, since the light of the moon is so exceeding small, it is manifest, why no sensible heat accompanies it.

However, though there is no proof, that a proportional quantity of heat does not always accompany every degree of light; yet on the other hand, it is manifest, that there is no necessity for the same degree of heat to be always attended with the same quantity of light; for many bodies will be very hot without shining at all.

Heat, therefore, is an effect produced by the rays of light, but may also be produced without them. But the sun's rays being the great instrument of the heat and warmth whereby all nature is invigorated, the consideration of light very naturally led the great sir Isaac Newton to enquire a little into so very important an effect of it. As a means to obtain some idea how heat is propagated, he proposes the following experiment. Let two thermometers, each included under a glass, be removed from a cold room into one that is warmer; and let one of the glasses be exhausted of its air, the other not: then it will be seen, that the thermometers thus inclosed will soon feel the warmth of the place into which they are brought; and that from which the air has been exhausted, will be affected nearly as soon as the other. In like manner, if the
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thermometers be carried from a warm room into a cold one, they will soon be affected by the cold of the latter place ; and that from which the air is withdrawn, will feel the change near as readily as the other. For greater satisfaction, he directs the experiment to be made in the dark, that the light of the place may not be suspected to have any influence in the success of the experiment. Now, as the thermometers cannot be affected without some agent to operate upon them, there is something within the glasses, by which this effect is produced. The air is extracted out of one of them ; it is not therefore the air that causes this appearance : nor can the heating of the thermometers be caused by particles of light latent in the air of the warm room ; for if so great a quantity of such particles were to rush on the thermometers, by being reflected from them, they would become visible ; for we have already shewn, that a less quantity of light, than what is sufficient to produce sensible heat, is very visible : and when the thermometers are affected, upon being removed into the colder place, it is still more manifest, that they do not grow cold by any particles of light escaping from them, because they could not but be seen. In short, there is no room to avoid supposing, that the glasses with which the thermometers are covered,

vered, do both contain in them some substance that will remain after the air is withdrawn, by the means of which the heat is communicated between the space within the glasses and the air without; so that the space within the glasses will receive warmth from the ambient air, when the glasses are brought into the warmer place; and when they are carried into the colder room, this substance within the glasses will propagate its heat to the air without; and by that communication of its heat, grow itself colder, losing from itself so much heat as it imparts to the other.

By this experiment of sir Isaac Newton, we see, that it is not by the air chiefly, that hot bodies communicate their heat to cold ones near them; nor that hot bodies have their heat diminished by the neighbourhood of those which are colder. An experiment, which I shall now make, will farther conduce to shew how heat is propagated. If a small wire be held in a flame, wherein it would speedily grow hot; when a larger body of metal, on which the flame cannot act so strongly, is contiguous to the wire, or only held very near it, in the same flame, the wire will not be affected so soon as when it is held in the flame alone: nay, I have held a very slender wire in a flame, under these circumstances,

stances, without being able to bring it to a red heat at all. We see, that the tallow in the wick of a lighted candle will not burn down to the very body of the candle ; but that the body of the candle keeps this tallow within some distance too cool for it to take fire.

(Here the experiments.)

These experiments, I think, evidently shew, that every hot body necessarily affects something without itself ; and when that substance without is indisposed to be so affected, the body cannot grow hot under that operation, which would otherwise have heated it : so that, upon the whole, we cannot doubt, but that the disposition of any body, which we term its heat, is owing to some substance every where present, which being in any place affected after some certain manner, will communicate heat to any body residing in that place, in proportion to the degree wherein the substance is so affected. What kind of substance this is ; what the disposition of it is, by which it heats bodies ; and how bodies are affected when hot, is in the next place to be considered.

Heat dilates and enlarges the dimensions of all bodies. This effect of heat has given rise to the invention of the thermometer ; which is nothing else than a vessel so contrived as to measure, with great exactness, the degree of expansion of

some fluid contained in it. All bodies, both fluid and solid, suffer this effect from heat ; that, when hot or warm, they take up more room than when colder.

The only exceptions to this rule are such bodies, which in some degrees of heat are fluid, but, by a sufficient diminution of it, become rigid and brittle. The most known example of this is water freezing into ice. Water contracts itself more and more by cold, like other bodies, as long as it remains fluid ; yet, as soon as it freezes and becomes ice, it expands itself again very remarkably. The like happens also to melted iron, which congeals into a brittle body ; though this is not so in other metals, which, when cold, are ductile : but this is owing to the change of texture which they undergo, whereby they are rendered brittle. It is manifest in ice, from its being less transparent than water, that its pores are become larger.

(Here thermometers shewn ; and the several rods extended by heating them ; also the pin and hole.)

The reason of this so singular an appearance we shall enquire into hereafter.

From this general effect of heat in dilating all bodies, it must be concluded, that heat puts the the parts of all bodies into motion ; for, without

some motion in the parts, the whole body could not be swelled. We shall find also, upon further examination, that the small parts of matter are put and continued, by heat, in a vibratory motion. By this, they emit, when hot to a certain degree, particles which affect the eye with the sensation of light. The sun seems only to be a great globe of matter heated so hot as to emit light and shine. Heated bodies also, by this vibratory agitation of their parts, emit fumes. The fumes which hot bodies emit, are suspended from falling down again by the air; but the air contributes nothing to their emission; on the contrary, it is an impediment. Bodies, when the pressure of the air is removed, emit fumes with a less degree of heat than they will do in the open air; as water will boil with a less heat in vacuo, than when exposed to the air: nay some bodies, when freed from the pressure of the incumbent air, will send out fumes, which, in the open air, never are known to emit any.

Having here made mention of the light emitted by bodies when hot, I shall shew whence the change of colour arises, which is seen in the emitted light, as the body increases in its heat. Almost all bodies, at first, emit red light, which by degrees alters, till with the most intense heat, the light becomes white.

Sir Isaac Newton has shewn, that the rays of light which affect the organ of sight with the colour of redness, are the least refrangible of any; the yellow light something more refrangible; the green still more; the blue more than the green; and the violet light most of all. Hence it appears, that the action between bodies and the red rays is the weakest; and in the rest the action is stronger, in proportion to the degree of refrangibility; and agreeably hereto, a less action of heat suffices for expelling the red rays than for the rest; and all the other rays are expelled, in order, as they are less refrangible. Whence the light first emitted by hot bodies is red; and with the increase of heat, it gradually changes, by the accession of rays of other colours, till being at length compounded of all colours, it becomes white. Where the heat is so strong as to throw out the blue and neighbouring rays in an over-great proportion, the light emitted is blueish.

Here, perhaps, it may not be amiss to obviate an objection, which this account of the emission of light from hot bodies may possibly suggest against what has been concluded in relation to the propagation of heat. It may be supposed, that the rays emitted by hot bodies, may not be confined within the limits of those
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which affect our organ of sight. The rays of light, as they approach to the extremity of the most, and also of the least refrangible, grow of so obscure a colour, that they seem gradually to lose the power of affecting our sense. Now, perhaps, it may be asked, whether bodies, not hot enough to emit lucid rays, may not, however, throw out some less refrangible than any we can see, which, by falling on other bodies, may excite heat in them. But, notwithstanding this supposition, we can know, that no such means as this is the primary cause of the propagation of heat. This is certain, from the observation before laid down, that a hot body does not only communicate heat to a cold body near it, but likewise, that a cold body will diminish the heat of a hot one brought into contact, or within a small distance of it: for this diminution of the heat can no way be effected by the intervention of these rays; for, by the cold body's reflecting them back upon the hot one, its heat would rather be preserved than lessened, since we see the rays of light, after reflection, excite heat no less than when they issue directly from the lucid body.

But to return, what kind of motion the parts of bodies have by heat, will appear from the due consideration of light.

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There is a mutual action between light and bodies; as light is emitted by hot bodies, so the rays of light, by falling on bodies, heat them, and are themselves refracted or reflected by the bodies. But the rays of light must heat bodies by acting on this substance, upon which their heat depends; consequently the reflection and refraction of light are caused by the same substance; for, as the action between light and bodies is mutual, without doubt, the effects on both are caused by a common agent acting between them. Now, several appearances in the reflection and refraction of light make it necessary, that some vibratory motion should be propagated by the light, through this substance, or medium; because it is found, that the light is disposed to be differently affected in different places, as it passes on, the same disposition returning successively at equal intervals. By these alternate dispositions of the light, I mean, those fits of easy transmission and reflection, into which, sir Isaac Newton has shewn that light is successively put, in its passage through transparent bodies.

But if this medium, or substance, of which we have been speaking, is put into such a vibratory motion by the rays of light; and, while it is thus moved, by its agitation heats the bodies
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on which the light falls ; it is manifest, what kind of motion it puts the parts of bodies into, when it heats them ; viz. the like vibratory motion.

In the last place, as elastic substances are the only ones through which this kind of vibratory motion can be propagated, we must conclude, that this medium, by which bodies are put into that disposition, wherein their heat consists, is elastic : and as our ear is so formed, that the vibratory motion of the air shall agitate the membrana tympani in that organ, in such manner as to excite in us the idea of sound ; so the vibratory motion of this more subtile medium will so agitate our organs of feeling, as to give us the sensation of heat.

Sir Isaac Newton, in speaking of this medium, has thought fit to distinguish it by the name of æther, or the ætherial medium.

Now, as the rays of light heat bodies, by exciting a vibratory motion in this æther, and thereby communicating a vibratory motion to their parts ; so other means of communicating such a motion to the parts of bodies, will produce heat.

A strong attrition, or collision of many bodies together, will cause a great heat. All metals, by hammering or filing, conceive heat : a small bar of iron, hammered briskly, may soon be brought

brought to a glowing heat: the iron, in the axle-tree of coach-wheels, if not well greased, whereby the brisk attrition is prevented, will heat so much as to set fire to the wooden axis: and, by striking fire with a flint and steel, the heat is so great, that the sparks which fall are no less than melted globes struck off from those substances.

Now, it is evident, that such collision must put the parts impressed upon, of those bodies, into a brisk motion: but since the vibratory motion of the ætherial medium will communicate such a motion to the parts of bodies, and action and re-action is every where equal, a quick vibratory motion in the particles of bodies must be capable of exciting also in the medium a vibratory motion, and thereby propagating the same through the whole body.

Why all bodies are not heated by motion and attrition, depends upon circumstances in their make, which are to be inquired into hereafter: but in the mean time, it may be observed, that those bodies which are most heated by the rays of light, are also heated most easily by these other means.

We shall likewise see hereafter, that there are still other means in nature of raising heat, without either the assistance of the rays of light, or a body already heated.

But

But now, upon the whole, what we know concerning heat amounts to this. The parts of solid bodies are not so fixed, and do not so unmoveably adhere to each other, as might at first be thought ; but even the most rigid are attended with a disposition, or rather power, almost continually varying, whereby their parts are sometimes removed farther from each other, and sometimes less : and this power is so extended round the body, that if a body be brought near another, less under the influence of this power it shall increase this power in that body, and farther dilate it ; but if the other body is more under the influence of this power than the first, the approach of the first shall diminish that influence, and cause that body to contract. When any body, by its contact or near approach, thus affects the sensible parts in us, if it causes them to dilate, it raises in us the sensation we call heat ; if it causes the parts of our bodies to contract, we feel a sensation, which we call cold : lesser degrees of the first we call warmth ; and small degrees of the other, coolness. These several terms relate to our sensation ; but when the state of bodies, as they are more or less acted upon by this dilating and contracting power, is considered abstractedly from the sensations raised in us, one term is sufficient to express it,

it, under the denomination only of different degrees of heat. When this heat is sufficiently great, bodies become luminous. Whence this light proceeds has been a question: some have supposed it to be only a pulse, propagated from the shining body to the eye, through an intervening medium, in the same manner as sound is propagated through the air, from the sounding body to the ear: but the circumstances accompanying the passage of light are inconsistent with this supposition. When the direct passage of sound to the ear is intercepted, it will take a compass round; a sound will come over a hill; but if any body not transparent is interposed between the lucid object and the eye, the sight of it is entirely lost. This, and some other properties attending light, leave no room for us to form any other idea of it, than as certain particles of matter propelled from the luminous body to the eye. But here another question arises, whether this light is emitted out of the body, or is a substance every where present, and is only protruded from the hot body, by that motion affecting the organ of sight. What has given rise to this latter supposition is this; that the rays of light are found to raise heat in all bodies upon which they fall: it has therefore been imagined, that they may be the immediate instrument

ment of heat, present in all places, operating to that end, even when they are not seen. But, as light is not always seen to issue from bodies, though considerably hot ; and there are means of exciting heat, without any visible assistance from the rays of light ; so no known properties of light qualify it to be the immediate instrument of heat, since it has been shewn, that the producing cause of heat must enable bodies to diminish, as well as increase, the heat of others. Hence it appears, that this supposed general presence of the matter of light in all parts of space, and the powers ascribed to it, are a mere hypothesis, not warranted by the appearances in nature.

On the other hand, that light may be lodged in bodies is evident. When the rays of light fall on any body, though a reflection ensues, by which the body becomes visible, yet scarce any body reflects back all the light incident upon it : most bodies retain the greater part which they receive within themselves. Hence all bodies exposed to the light of the day must have within a portion of the material of light, where, probably, it is no useless part of their composition, since it has been found, that those properties in light, whereby it is ordinarily reflected, and refracted, or renders bodies visible, are not the
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only qualities it is possessed of. And if light be a requisite ingredient in the composition of bodies, no wonder, that by heat it is emitted from such as are taken from the deepest recesses of darkness, as well as from those which constantly communicate with the day. Even the subtle matter, whatever it be, in electrical experiments, contains and emits light: that it is not composed simply of rays of light is certain; for they widely differ in properties. The reflection of light in those experiments is accompanied with a sound, and even smell: this matter passes not through all transparent substances indifferently, like the rays of light; it does not pass through water as it does through glass; and through glass it passes without refraction. By this it appears, that it does not consist of mere rays of light; but that light is an ingredient in its composition, and occasionally struck out of it, accompanied with a degree of heat, productive, when the matter is copious, of very sensible effects.

As it has been shewn, that the dilatation of bodies from heat is effected by a vibratory agitation of their parts; from this it is, that heat is the great instrument, in chemistry, for resolving bodies into their principles; for, when this agitation is increased beyond a certain degree, the

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parts of mixed bodies separate from each other, and the similar parts associating together, appear under a new form, from what they did in the compound.

But, before I proceed to consider more particularly the several principles, into which bodies are divided by the fire, it will be convenient to shew the various ways, in which heat is applied by the chemist to the bodies, whereon he operates : and this shall be the subject of our next meeting.

* To find the proportion between the quantities of light we receive from the sun and from the moon.

PROPOSITION I.

If two bodies are equally luminous, the quantity of light we receive from each is in the duplicate ratio of the sines of half their apparent diameters.

The quantity of light received from two equal bodies at different distances, is in the reciprocal duplicate proportion of the distance ; and the sines of half the apparent diameters of the bo-

* The three following propositions were not, I presume, read in the course of the lectures ; but as I find them in the doctor's manuscript, I have thought fit to print them.

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dies are in the reciprocal proportion of their distances ; therefore, the light received from two equal bodies, at different distances, is directly in the duplicate ratio of the sines of half the apparent diameters.

Moreover from two bodies equally luminous at the same distance the light received is as the surfaces from which the light is emitted, that is in the duplicate ratio of the sines of half their apparent diameters. Therefore if neither the distances nor the bodies are equal, yet still the light received from each will be in the duplicate ratio of the sine of half its apparent diameter.

PROPOSITION II.

The density of the sun's light at the moon, is to its density, when emitted from the surface of the sun in the duplicate ratio of the sine of half the angle, under which the sun is seen from the moon to the radius.

The light emitted from the surface of the sun at the moon is dispersed over the surface of a sphere, whose centre is in the sun, and its semi-diameter the distance between the sun and moon. The density therefore of the same quantity of light being reciprocally proportional to the surface over which it is spread ; the density of the
sun's

sun's light at the moon will be to its density at its exit from the sun's surface, as the surface of the sun to the surface of the forementioned sphere; that is in the duplicate ratio of the semi-diameter of the sun to the distance of the moon and sun, or in the duplicate ratio of the sine of half the angle, under which the sun appears from the moon to the radius.

PROPOSITION III.

To find the proportion between the light we receive from the moon at the full, to the light we receive from the sun, upon supposition that the moon reflects all the light incident upon it.

By Prop. I. if the moon and sun were equally luminous the light received from the moon would be to that received from the sun in the duplicate ratio of the sine of half the apparent diameter of the moon to the sine of half the apparent diameter of the sun. But the density of the sun's light at the moon is to the density of the sun's light at the sun's surface, in the duplicate ratio of the sine of half the angle, under which the sun appears from the moon to the radius, (by Prop. II.). Therefore if the moon received the light of the sun upon all parts of the hemisphere obverted

toward the sun under the same degree of density, and reflected all the light incident upon it, and were at the same distance as the earth, the light reflected to us from the moon would be to the light received from the sun in the duplicate ratio of the sine of half the moon's apparent diameter to the radius. But at the full, the moon being somewhat further distant than the earth, the light received from thence is somewhat less.

But all parts of the moon's surface, by reason of its spherical figure, receive not the sun's light incident upon it under the same degree of density. The moon receives on its whole surface no more light than can fall on so much of the surface of the sphere, wherein the moon moves, as is included within the moon ; that is about half as much, as if the sun's light fell on all parts of the moon with equal density ; therefore, the light received from the moon will be but half what is above assigned, though the moon reflected all the sun's light incident upon it.

LECTURE III.

THE operations of chemistry, may, in general be divided into two species, analysis and composition; by the first bodies are resolved into their constituent parts or principles; by the other the productions of this analysis are recomposed with one another, or with other bodies: indeed all mixture of bodies, where an artificial application of heat is requisite to procure or assist their combination may be ranked under this synthetic branch of chemistry.

With respect to the analytical part, the effect of fire in general upon most compound bodies is to drive a part off from the rest in vapour, while another part remains behind, and bears the force of the fire unmoved: some bodies, indeed, are wholly raised in vapour, and others remain entirely unmoved. This has occasioned a general division of substances into fixt and volatile; those being volatile, which fly away in vapour; and those fixt, which remain behind. Perhaps there are no substances to be found here on the earth, which will endure

above a certain degree of heat, before they are dissipated ; but this division of bodies into fixt and volatile substances has relation to the force of fire usually applied by chemists : these terms are merely relative ; and as those substances, which become volatile with one degree of heat, may remain fixt in a less, so it is usual to compare substances together both in degree of volatility and of fixity ; those bodies being accounted most volatile, which fly off with the least heat, and those the most fixt, which endure the strongest fire. We as often speak of substances as more or less fixt, as we do under the notion of more or less volatile. Nor is it to be understood, that there is one established degree of heat, which discriminates the substances, that are to be ranged among volatile ones, from those which are to be ranged among the fixt : the same body may have both terms applied to it, as it shall be compared with different bodies ; but it is most usual to compare the effect of small degrees of fire on bodies under the notion of volatility, and to use the other term of fixity, when the effects of strong fires are considered.

If we have recourse to what was said in the preceding lecture concerning the operation of heat on bodies, we may form some judgment
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of the properties required in bodies to render them volatile.

The action of heat is to communicate a vibratory motion to the particles of bodies, before those particles can become volatile, and fly off from the body, to which they are joined, they must suffer such a degree of agitation, as will separate them, and set them free from the body they adhere to. Therefore the stronger any particles adhere to the rest of the mass, the less volatile will they be. Thus we find, in chemical processes upon heterogeneous bodies, many substances to be exceeding volatile, when separated from the compound; which yet require a great force of fire to expel them thence.

Another condition necessary to render particles of matter volatile, is such a constitution, as disposes them to be easily agitated by heat. One condition, that may be conceived to render a body more easily put into motion, is the having a rare structure, or but a small quantity of matter in proportion to its magnitude. It is certainly not necessary, that all volatile particles should be smaller in bulk than others; for we shall see, that very fixt substances will unite themselves with volatile ones, so that the compound shall be volatile: and in this case, the volatile particles are larger than the fixt were;

for the fixt are become volatile by the accession of new matter. But here the great rarity of the added part may make the whole to be lighter, in proportion to its bulk, than the fixt particles alone were.

However the particles, whose specific gravity is least, do not for that reason only make the most volatile substances; but the former consideration must be joined with this, when we judge of the volatility of a body: thus oil, by the great tenacity and adhesion of its parts together, is much less volatile than water, though its specific gravity be less.

What the absolute minuteness of the particles of matter may contribute toward their volatility, would best be determined, if it could be known, whether the æthereal medium, which we proposed in the preceding lecture to be the immediate instrument of heat, acts only on the surface of these particles, or acts also on their internal parts. If it acts only on the surface, the minuteness alone of the particle may contribute towards its easy elevation, because the smaller a particle is, the more surface there will be to be acted upon in proportion to the magnitude of the particle. A globe, whose diameter is half the diameter of another globe, is but one eighth part of the bulk of this other, but has

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one fourth part as much surface ; therefore, the surface of the lesser globe is twice as great, in proportion to its bulk, as the surface of the greater. If the ætherial medium, as it pervades the particles, acts also with equal force on the internal parts, the absolute magnitude of a particle must contribute little toward its volatility.

But thus much is here observable, that this ætherial medium is so altered at the surfaces of bodies, that it there only acts on light in refracting and reflecting it ; why may it not therefore act more forcibly on the particles of bodies at their surface, than on their inward parts ?

However, we shall hereafter find some farther circumstance concurring to vary the volatility of bodies, viz. their abounding, more or less with an active principle found in some degree in all bodies, which the chemists have called sulphur. Perhaps, from hence must be deduced the principal cause of the diversity in the volatility of different substances.

But to proceed, as it is the design of chemistry to bring under examination all the parts, into which bodies are resolvable by the fire, the body examined is to be lodged in such a vessel, as may assist in collecting the ascending vapour.

There are two kinds of vapour, which arise from heated bodies ; one sort condenses into a
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liquor ; the other under a dry form. Separating the liquid vapour is properly called distillation ; raising the dry vapour is called sublimation.

The most general instrument of distillation is the retort, where the ascending vapour passes through the neck, and is received into another vessel fitted on to it, and called from this office a receiver. These vessels are usually made of glass, that being a material, in which the subject can be kept perfectly clean, and free from the least taint. In cases, where a greater heat is necessary, than glass can support without melting ; instead of the retort we make use of an earthen vessel, usually called a long-neck ; this is formed of a shape something different from the glass retort ; because, in some of the substances, which are distilled with these vessels, the vapour rises very sluggishly, and will not ascend far ; therefore these vessels are so shaped, as to give the vapour a more horizontal passage. Sometimes the neck of these vessels is made crooked, and then the vessel is called a crook-neck.

In cases, where it is necessary to put to distillation a great quantity of materials, and where the vapour is so copious, as would require a receiver of immense bigness to contain it, a particular contrivance is made use of to condense the vapour in its passage. For this end the

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vapour is let pass through a contorted pipe, or worm, lodged in a vessel filled with cold water, by the coldness of which, what enters the worm in vapour, runs out condensed into a stream of liquor. The vessel here used to hold the matter to be distilled is too large to be made of glass; it is usually made of copper, which being well tinned within is sufficiently secured from giving any tinge to those kind of substances for which this vessel is made use of. This vessel is commonly called a copper still, and the pipe, through which the vapour passes, is fixed to a head, which lifts off from the body of the still, for the convenience of putting the materials in and taking them out: this head is properly called the alembic. These are the vessels used by the distillers in drawing their spirits. In small stills of this kind, a more compendious method is made use of for condensing the vapour, which is by including the head itself in a vessel of water.

There is also another method of performing the operations, for which these instruments are commonly used; which is by what is called the cold still, because here a much less heat is used. The material to be distilled is laid on a copper or iron plate, first covered over an inch thick with sand or ashes, or put into a leaden
pot

pot set upon such a plate. Over this is placed a conical head to receive the ascending vapour, which by a nose fixed in this head descends into a receiver. The fire must be kept very low, that the vapour may rise so slowly and so cool, as not much to heat the head, which receives it, that it may condense without any help, except, perhaps in some cases by laying a wet cloth upon the head of the still.

There are also smaller vessels, of a like structure with the copper body and alembic now described, made of glass, which are but little used by the practical chemists. However they are sometimes convenient, when we desire to separate very volatile substances from each other; for then a tall glass of this form is best fitted to give room for the most volatile substance to separate from what is less volatile, by rising higher: with a low glass it is not so easy to prevent their ascending together.

These glasses are also useful in collecting dry vapours, or in sublimation, the head or alembic being made without a beak, which is usually called a blind head. How the practical chemists supply the use of this vessel, shall be shewn, when we come to operate on the particular substances, upon which they usually perform these sublimations.

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But these subliming vessels are only to be used, when the vapours easily ascend. When they require a strong fire, and are forced up with difficulty, it is usual to put the matter into a globular vessel with a long stem, called a matrafs, or bolt-head: here the vapour ascending, fixes on the upper part of the globe.

When a large quantity of materials is to be sublimed, an earthen jar covered at top with a moveable iron plate is sometimes made use of.

When what rises from a body, while heated, is to be neglected, and the operator's intention is only to regard the change wrought by the fire, on what remains fixt in it, such subjects are sometimes put into iron vessels, as pots, ladles or the like, often into earthen ones. Of this kind are crucibles made of an earth, that will well endure the fire. For some particular purposes vessels are made of the ashes of burnt bones, or of horns of animals burnt, which latter are preferred. These are particularly necessary for the refining of silver, as we shall see hereafter. They are called cupels, or tests. The method of making them is to moisten the ashes, till they will just stick together, when pressed in the fingers; and then to stamp them hard in a brass mould. Sometimes these ashes are stamp-

ed into an iron ring, and put along with the ring in the fire.

The operations, which materials undergo in all these vessels, may be reduced under the two general names of melting and calcining.

These are the vessels of most general use in the analytical part of chemistry. In the other part, which concerns the mixing bodies, for such an artificial application of heat as may be required to effect their combination and union, but few instruments are in general requisite: except the common instruments of pots and kettles, or the like, the glass-body and bolt-head above described are for the most part sufficient.

When the stem of a bolt-head is closed, by inverting a less glass of the same kind into it; if the heat applied raise any vapour from the included materials, at the height of the upper bolt-head, it will cool and fall down again; by this means, if the glasses, before they are joined, be made warm, any liquor may be boiled without wasting in vapour.

Two bolt-heads thus joined compose, what the chemists call circulating vessels. We find in books other vessels also of a more complex form described under this name; but they have no advantage over these here mentioned.

If the stem of the bolt-head be continued also downward into the body of the glass, and left open by a very small orifice only, the bolt-head is then called an infernal glass: but this is a contrivance useful only for some particular purposes, to be explained hereafter.

The next thing now required is to explain the method, by which the junctures of vessels are to be closed; for when a vapour is passing, from a retort for instance, into the receiver, unless the juncture be closed, where they are fitted together, a part of the vapour will escape. This closing up the junctures of vessels is called luting, and the materials, by which it is performed, lutes.

Lutes are of various sorts. For instance wheat-flour and water spread upon a fillet of linen or paper makes a good lute to hold in watry vapours raised with a small heat.

Horse-dung, mixt with twice its quantity of fine clay or loam makes a good luting for most purposes. This is the luting chiefly used by the practical chemists.

Windfor loam, wherewith the bricks are best laid in furnaces, that are designed to endure a strong heat, makes alone a very good luting, and is therefore most convenient, for those who exercise chemistry for entertainment or speculation ;

lation; but those, who follow it as a trade, prefer that which is least expensive.

Whiting, flour, and house-sand in equal proportion made into a paste with strong brine is also a commodious luting.

In authors we meet with the description of several other lutes, but these are sufficient.

Sometimes glasses are shut up by heating their stem red-hot, and the opening either melted up, or pinched close: this is called sealing hermetically.

In chemical operations the luting most generally used is loam, as before mentioned. If this be applied to the juncture of the glasses so closely, and so long before the operation is entered upon, that it shall become perfectly dry, and would close the juncture so absolutely, as to hinder any manner of air or vapour from finding its way out; when the glasses grow in any great degree hot, they must necessarily be broke by the expansion of the air alone imprisoned within them. If the luting be applied immediately before the operation, the ascending vapour will keep it continually moist, and thereby will escape too freely through it. It is best to lute the vessels one day, and make the fire the next: by this means, the luting will not be so very close,

close, but that it will give a little passage to the included air upon its first expansion, and will dry, as the glassess grow hot, timely enough to hold in as much of the vapour, as is consistent with the safety of the vessels. The luting above described, with whiting and flour, hardens more easily, and therefore need not be applied any length of time before the operation is begun.

Many of the chemical glassess come from the glass-house with long, and sometimes irregular necks, that it is often necessary for the chemical operator to cut a part off, before he lutes them together. This is usually performed, by heating them, where they are to be cut, and touching them with a little moisture, which causes them to crack, and the superfluous part to fall off. The glassess may be heated either by a hot iron ring of the size of the glass to be cut; or by binding round them a thread dipped in oil of turpentine, brimstone or the like combustible substance, and setting the thread on fire. With the iron ring the glass most commonly breaks off without wetting. Small pipes of glass are best broke by notching them with a file, and then breaking them off with the fingers.

The next thing to be considered is the method of applying the fire in chemical operations,

tions. In these operations it is a necessary circumstance, that the fire be carried on regularly, either the same degree of heat continued, or equally raised without wavering. For this end, when the fire is not to be of the most violent kind, the vessel, containing the substance to be operated upon, is not usually exposed to the naked fire, but is rather heated by the inter-mediation of some body between. Water is a commodious medium, when no greater heat is required than what water, when boiling, conceives, because the heat of boiling water is never to be augmented. The different force of the fire under it may cause it to boil away faster or slower; but when it once boils out freely, its heat will never after increase.

Water thus applied chemists call *balnæum Mariæ*. Sometimes they direct the distilling vessel to be placed in the vapour only of the water. This is called distilling in a vapourous bath, and is a less heat than the other.

Horfe-dung also affords a very steady heat, and is of long duration. This is a very commodious heat to promote putrefaction. With this heat also the vapour of vinegar is raised, for corroding of lead, to make cerusse or white lead, as will be particularly explained hereafter.

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When these heats are not sufficient, sand is made use of. The practical chemists generally make use of sand for every heat, from the least to the greatest, sand is capable of. For this end a pot of cast iron is set in a furnace of brick, so built that the fire may play well round the pot, and heat it as equally as may be. It is usual to carry the flame and smoke from this fire under an iron plate covered with sand, before it passes up the chimney; by which means they have a smaller heat of sand to be used at the same time with the pot, without an additional expence of fuel.

Filings of iron would give yet a greater heat than sand.

The advantage of interposing all these kinds of substances is, that their heat is not so fluctuating, as that of an open fire; for when the fire is quite put out, their heat will continue a considerable time; and when the fire rises, their heat does not increase at the same instant with it, but follows it gradually.

However, when a greater degree of heat is necessary, than what such substances will give, an immediate fire must be made use of. This is of two sorts. The mildest of these is an open fire, such as may play on the bottom, and about the sides of the vessel in the man-

ner, as the iron pot before mentioned is heated.

When glass vessels are to be exposed to this fire, it is necessary to cover them over with an earthy coat. This may be made of potter's clay, mixed with sand till it loses its unctuousness, and will no longer stick to the fingers ; or sand may be mixt with the forementioned luting of clay and horse-dung. Windsor loam and Stourbridge clay, with which the pots of the glass-house furnaces are made, are still better sorts of coating, used alone without any mixture.

The reverberatory fire, where the fire being made under the vessel, the passage for the flame and smoke is directly over it, gives still a greater heat than the open fire now mentioned ; for here the flame encompasses the whole vessel, beating on the very top, as well as on the bottom and sides. In this fire, earthen vessels are only to be used.

There is also another kind of reverberatory heat, when the fire is made on one side of the vessel containing the matter to be wrought on, and the flame draws over the vessel to its exit through the chimney. In this, the greatest heat is applied to the upper surface of the subject.

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There is also another method of accommodating the greatest heat to the top of the subject, which is by placing the subject under an earthen cover, and heaping the fuel over it. This cover is usually called a muffle ; and the furnace wherein it is used, must have an opening to correspond with the mouth of the muffle, by which the subject to be wrought on may be taken in and out. In a furnace of this kind, called from its use an essay-furnace, are made the essays of wrought plate at Goldsmiths-hall.

When the fire is required to be the strongest of all, a wind-furnace is made use of ; which is a furnace so built, that there may be a very strong draught of air to blow the fire, and give it the greatest strength possible. A blast also, with large bellows will procure a very strong heat ; but these bellows must be double, after the manner of those used by the smiths, that the blast may be continual ; though no heat can be raised by this means, to exceed what may be obtained in a good wind-furnace. The principal use of bellows is, when a great heat is required to be excited very quick.

The flame of a lamp blown to a point by a small pipe gives a very strong heat, and is often applied to melt small pieces of metal or the
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like. Workmen often use it in soldering small work.

In relation to the kinds of fuel, it is to be observed in general, that charcoal gives the strongest heat, this fuel having no humidity like wood or coals. Coals give the most intense heat, after their humidity is evaporated, and they cease to flame.

Oil also and spirits are made use of burning in a lamp, when a small quantity of materials is to be wrought on, and the degrees of heat these lamps will afford, are sufficient. This is, in particular, a commodious method of continuing a constant heat for a great length of time; for it is easy to have a lamp, that will keep burning twelve hours or more.

There is also another method of continuing a heat in one constant degree without much attendance, by the furnace usually called an athanor, or tower-furnace. This furnace is a tall cavity raised on a grate, which has an ash-hole underneath: this cavity is called the tower of the furnace. In the side of this tower at a proper height above the grate is a passage for the heat to pass out of the tower under an iron plate covered with sand. There is sometimes a slide over this passage, whereby it may be widened

dened or straitened, and the degree of heat varied by that means. Now when the tower is filled up with coals, if it be well closed at top, no more of the coals will burn, than what lye between the grate and the passage before mentioned for the heat; because here, and no higher, will be a current of air to blow the fire: all the rest of the fuel above is only a supply to what shall be burnt to ashes, and fall away through the grate; so that the height of the tower adds nothing to the strength of the heat, but the higher it is, the less frequently will the fuel require to be supplied. In this furnace therefore a constant heat both night and day may be continued for any length of time with very little attendance.

The fuel in this furnace must be charcoal or some other such-like fuel, that will burn away to pure ashes. Sea-coal, by caking into cinders, will soon stop up the grate and put the fire out.

The method invented by Vigani of erecting furnaces, is very convenient for those, who have not a fixt laboratory. His furnaces are composed of bricks ground to a pretty true square, and made all of the same breadth, and of the same thickness. The bricks being ground, they will lie close enough to confine the heat

without being fastened together by any cement.

Three or four rows of bricks are first to be set edgewise, for a grate, or to make a greater heat a second order placed in like manner across these, and where the greatest heat is required, a third or a fourth. Over these, the furnace is to be formed differently according to the purpose, for which it is designed. By this method a furnace may be fitted for any chemical operation whatever, even to the melting metallic ores, which are operations, that require the greatest heats of any.

The best fuel for these furnaces is charcoal: Scotch coal also burns in them very well.

In furnaces, where strong fires are used, it is of great consequence to choose a proper earth for the bricks, wherewith the furnaces are built. There are two qualities in earths, that dispose them to bear the fire, to be considered distinctly: one is, not easily to be melted, the other not to be disposed to crack in heating or cooling. Earths more easily melt by being charged with metallic particles: the earths that burn red abound in iron particles, and are therefore more apt to melt than those earths, that burn white. The earths, that burn into a hard brick,
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are most apt to crack by the fire, which is an effect common to all brittle substances : glass is the most subject to it of any thing. The cause of this effect is the dilatation, which I observed, in the last lecture to be the effect of heat upon all bodies ; for in these hard and brittle bodies, if they heat in different parts unequally, or if in cooling, a blast of cold air, or any other accident, too hastily cools one part ; the body not being of a yielding substance, the contracted part separates from the dilated, and the body breaks.

In the glass-houses they are principally solicitous to find an earth, that will not melt with the violence and long continuance of those fires. A clay dug up near Stourbridge, in Worcestershire, thence usually called Stourbridge clay, is found the fittest for this purpose, with it the pots are made, in which the glass is melted, and the inside of the furnaces themselves used to be built : but lately a stone has been found near Newcastle, which at less expence answers the same purpose. Their fires being kept on continually for a great length of time they are less subject to be incommoded by the breaking of the earth ; though, in their pots, they often suffer by that accident.

In other furnaces, where the fire is often varied and extinguished, a loose sandy kind of brick is most commodious; for the parts of this brick hanging loosely together easily yield to that alteration, which the change of heat makes in them. Those called Windsor bricks are the best of any in this country; and should be laid in Windsor loam, not in mortar.

When it is necessary to make any vessel of the harder clay, that must undergo frequent changes of heating and cooling; to secure this earth the better from breaking, with the fresh clay is sometimes mixt a good portion of what has already been burnt, broken into pretty gross pieces. By this inequality in the texture the compound becomes something more durable. In this manner the Hessian crucibles are made; and also the pots in which they make brass in England.

In great part of chemical operations divers materials are mixt together, and as they are usually proportioned by weight, I shall conclude this lecture with a brief explanation of the several weights in use.

In England, we make use of two different pounds: the one is called the pound avoirdupoise,

poise, and the other the pound troy. The pound avoirdupoise is something larger than the other. It is that, by which large quantities of most goods are bought and sold. In this weight, what is called the hundred weight is not a just hundred pounds, but contains a hundred and twelve of these pounds: and twenty such hundred weights are called a ton. This pound is divided into sixteen ounces, and the ounce into sixteen drams. In this weight more minute divisions are not in use.

The pound troy is divided, by the silversmiths, for weighing of silver, into twelve ounces, each ounce into twenty pennyweights, and the pennyweight into twenty-four grains. At the mint they subdivide the grain into twenty parts called mites. Gold is also weighed at the mint by this pound, but otherwise divided; the pound being here divided into twenty-four parts called carats, and each carat into four parts called grains: so that a grain of gold is equal to sixty grains of silver.

The carat by which jewels are weighed, contains only four silver grains.

The physicians also prescribe by the pound troy, but divide it still otherwise. They have
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twelve ounces in the pound, but divide the ounce into eight drams, the dram into three scruples, and the scruple into twenty grains, whereby the grain becomes the same as in the division of the silver weights.

Though the extempore prescriptions of physicians are always adapted to the troy weight, and the officinal compositions are described in the generality of pharmacopœias by the same divisions of the pound; yet it has been a custom pretty general among our apothecaries to mix the ingredients of those compositions by the avoirdupoise weight; though the ounce in this weight bears a different proportion to the pound, than in the troy weight. But, in the present Pharmacopœia, this error is particularly guarded against.

Though the pound in the avoirdupoise weight is heavier than in troy weight, the ounce in the former weight is less than in the latter; so that ten troy ounces nearly equal eleven avoirdupoise; and seventeen pounds troy is very little short of fourteen pounds avoirdupoise.

The assayers, who examine very small quantities of metals, use still other weights. They take a small weight, which they call their pound,

pound, and divide this pound, as the troy pound is usually divided. Their pound for silver essays is about eighteen grains, and for gold essays six grains. The reason, that the silver pound is treble of the gold pound, is because in assaying of gold they mix silver with it in that proportion. The only convenience of this is to find names for the very minute weights, they must make use of, and to save the trouble of computation in their essays.

They have another artifice of more consequence in order to their weighing with exactness, which is to set their scales under a glass, which they call a lantern, whereby they keep them from being tossed about by the air.

Their scales are in general made so tender as to turn, with the hundredth, or even with the two hundredth part of a grain, sometimes with less. If they turn with the three-hundredth part of a grain, they will distinguish in a silver essay to a single grain. Though the assayers are not accustomed to report their essays of silver nearer than to a half-penny-weight, nor the essays of gold nearer than to one quarter of a gold grain.

It is also convenient in assaying metallic ores to be provided with a small weight to be
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called a ton, and divided in the same manner as the common ton. Though for this purpose the common troy weights are of themselves not inconvenient; for if the ounce be considered as a ton, the pennyweights will represent hundreds: but for the divisions of the hundred, either computation, or an express set of small weights must be used.

LECTURE IV.

THE several substances, into which bodies are divisible by the fire, differ greatly from one another. However there are some general characters, by which they may be reduced under a few heads. Chemists have reduced them to five, three volatile, water, or phlegm, spirits and oils, and two fixt, salts and earths. These are commonly called the chemical principles. By water is meant a fluid without taste, smell, or any other sensible quality to distinguish it from common water. By spirits are understood all fluids, which mix with water, and are endued with other properties than water itself. Oils are fluids, which will not mix with water; and these are also inflammable, contrary to the nature of water, which extinguishes fire. These are the three divisions, under which chemists range the fluids, that are separable from mixt bodies. The other two heads of salts and earths comprehend the solid parts yielded by the mixt. A salt is whatever dissolves in water, and unites itself so with it, as to make with the water one body, and to pass through

through the closest strainer without being severed from that water.

The method of straining used by the chemists is most commonly with paper after this manner. They fold the paper so, that it may fit the cavity of a funnel, and pour the liquor into it; and the liquor, as it ouzes through the paper, runs down the neck of the funnel. Straining in the language of the chemists is most usually called filtering, and the strainer a filtre. Most of these substances called salts, since they are not volatile, and fly away as soon as heated, melt and flow in the fire like metals. The other solid substance separated from mixt bodies, is that, which remains, after all the foregoing are separated, and is a dead earth without any sensible properties, but those which are necessary to the constitution of mere matter. It will not dissolve in water as salts do, nor will it melt in the fire. If it be ever so much agitated and mixt with water, it would soon subside from it again, being specifically heavier: in the fire it remains unaltered. This substance seems to be the basis of bodies, and to give them their shape and texture.

Water is the principle, which seems to be the most simple, next after this earth. It is surprizing to see, how great a quantity of it is to be

be drawn from bodies, which appear perfectly hard and dry. There are scarce any bodies, besides stones and metals, that do not yield a considerable quantity upon distillation. The particles, which compose it, join themselves to the other parts of bodies, and unite so with them, as to shew no signs of humidity; yet, when separated, forthwith assume their native form. This fluid, by so freely uniting itself with other substances, becomes the chief instrument, next after heat, of natural operations: for the active parts of matter, by swimming in this fluid, move themselves, and follow without impediment the influence of those powers, by which they operate. Without this fluid to give easy motion to the particles of matter, the powers of nature could have very little effect. Thus we see, that water conveys to all plants their nourishment; and the food of animals is rendered fluid by the digestion of the stomach, before it can be carried farther into the body, and be made use of for its nourishment.

This principle of water is possessed of a more extended power, by which its parts adhere together, than what is to be found in the earth before mentioned. For wherever water is laid on any thing, which it will not wet, as upon what is oiled, it forms itself into spherical drops

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by the mutual attraction of its parts; and, when mixed with the forementioned earth, it causes the parts of that to adhere firmer together than before. But notwithstanding this power of cohesion between the parts, wherewith water is endued, a small degree of heat serves to make the parts adhere so weakly, as to keep it fluid; though we find a certain degree of cold will permit it to form itself into a very hard mass in freezing.

This effect of the absence of heat upon water deserves well to be considered. Water contracts in its dimensions by cold, as all other bodies do; until such times as it freezes. Then it swells again.

The cause of this so remarkable an effect we have promised particularly to inquire into.

The academy erected at Florence for the cultivation of natural philosophy, which was the first of those societies in Europe, have long ago made very many judicious experiments upon this matter.*

There are certain mixtures, whereby so very intense a degree of cold may be procured, as will speedily freeze water.

Ice in powder, or snow mixt with common

* Saggi d'Esperienze di Acad. del Cimento, Firenze, 1667.

salt, nitre, and some other salts, will soon freeze a small vessel of water set into such a mixture. It is to be observed, that the ice or snow always melts, before it produces this effect. At the instant of its melting it gives the most intense cold. After this its cold gradually diminishes by the warmth of the circumambient air. The cause of this freezing power I conceive to be, as follows. Any of these ingredients, which mixt with the snow or ice produce this cold, are such as being mixt with water, are a great impediment to its freezing. This is a known effect of common salt, the most usual ingredient, with which freezing mixtures are made. These ingredients do not hinder the freezing of water by keeping it warmer. But as the freezing of water is owing to a disposition peculiar to that fluid, these substances hinder it, by changing that disposition. Any of these materials being mixt with ice already formed, soon reduce it to the same liquid state; they would have kept it in, had they been mixt with the water before its freezing. And the ice is here dissolved without losing any thing of its coldness. Now the coldness of ice, if it can be communicated to water without diminution, will freeze it, for the degree of cold in the ice is that, which retains it in that form, and prevents it from returning to

water, therefore that degree of cold, communicated to other water, must turn that also into ice. Now a heap of snow or ice in powder is a collection of particles of ice, with interstices between filled with a warmer medium. Therefore, if any vessel of water be set into such a heap of snow or ice, the cold communicated to the water will be no greater, than what results from the coldness of the ice or snow compounded with the warmer condition of the interstices. But when the snow or ice is liquified by the means before mentioned, then the vessel is surrounded by one uniform body of cold equal to that of a solid body of ice. Therefore in this case the water in the vessel will freeze, in the other case not.

The ingredients mentioned may something hasten this effect, in that being put into water, they increase its coldness, while they are dissolving in it, as we shall see hereafter. Though common salt will assist but little on this account. Nay vinous spirits, will not only quicken the freezing power of these mixtures by hastening the liquidation of the ice, as the forementioned gentlemen observed; but will alone produce the same effect, as successfully as the salts themselves: yet these spirits in mixing with water give an additional warmth to it.

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The gentlemen of the forementioned academy plunged a globular glass with a very slender stem into such a freezing mixture, as we have now described, the glass being filled with water till it rose to some height in the stem. At the first immersion of the glass they observed the water to rise, but soon to subside again, till it sunk sensibly below its first height. The rise of the water on the first immersion of the glass they soon perceived to be owing to this cause, that the glass by being in immediate contact with the freezing mixture was first affected by the cold, and by contracting diminished its cavity; but when the water began also to be affected, it sunk again and continued to subside; till at length it would rise again, at first slowly, but in a little time very fast. As soon as this motion was over, the glass being lifted out of the freezing mixture, the water was found to be frozen. By repeating the experiment often, and frequently raising the glass out of the mixture, they sometimes had the good fortune to take it out, at the instant it was going to freeze, so that it would sometimes freeze before their eyes. In this case upon lifting up the glass, the water would appear as clear and transparent as ever; but on a sudden would become opaque, and at the same time rise up in the stem of the glass:

and then the water was frozen. This opacity of ice above water explains the whole mystery of the dilatation of the water upon freezing. Sir Isaac Newton has clearly proved, that the transparency of bodies is owing to the smallness of their pores; and that nothing more is necessary to render a pellucid body impervious to the light, than to render the pores of it large enough. Thus, when the most transparent glass is beaten to powder, the powder is opaque, or impervious to the light. Why the largeness of the pores of a body produces this effect, sir Isaac Newton shews at length, viz. by the light's suffering successive reflections at the surfaces of each particles, as it passes through the pores, till it is wholly lost.

By the great opacity therefore of ice in respect of water, we know that the particles of water in freezing unite into little masses, and form larger particles, which necessarily occasion great pores between them. And by this means they compose a body, which takes up more room than before, while they ranged themselves in a more uniform manner. That the particles of water should take such a difference of arrangement upon cold, as to enlarge the bulk of its body, must be owing to their particular make and constitution; perhaps to the configuration

guration of them; for oils will grow thick and opake by cold without swelling thus; nor do they become hard and brittle, as water does. But this property of dilating upon changing from a fluid state to a solid, is not peculiar to water alone: it is common to all bodies that melt into a fluid, and are brittle when cold.

(Here freeze a water-thermometer with snow or ice and salt; and with the same and spirit of wine.)

In the next place, to consider salts and spirits; after having given the essential characteristics, whereby salts are to be distinguished from other substances, it will be proper to explain the grand division of them into acid and alkali, which has made much noise among the natural philosophers. All the principles in philosophy of some men have been confined to these two. This division of salts does in reality deserve our greatest attention. But as all spirits, except the inflammable vinous spirits, seem to be only a dissolution of some salt in water; in what I am going to say upon acid alkali, I shall speak of salts and spirits promiscuously.

An acid is properly that, which tastes sour, when applied to the tongue, whether it be a dry powder, or a liquor, that is, whether it be salt or spirit: for it is to be observed, that of

dry bodies salts only are the proper subjects of taste, for earths being undissolvable in water, and unactive substances, will not dissolve in the saliva nor act upon the nerves of the tongue, otherwise, than as by drying up the humidity, wherewith the tongue is moistened, they may create a perception, which in the common phrase of speech may be comprehended under the general name of that species of sensation, to which this organ is appropriated. The alkalis are such salts and spirits, as, when mixt with acids, raise a conflict and effervescence, and in the end deprive them of their acidity. Some acids will ferment with each other. Oil of vitriol for instance ferments with the weaker acid of spirit of salt: but here the mixture still remains acid.

(Here the experiments of acids fermenting with alkalis.)

What this fermentation is, and to what cause its visible effects are owing, will be inquired hereafter.

Sir Isaac Newton seems to think, that the acid principle is the great agent in nature, which sets at work the other parts of matter. There is a paper written by him particularly upon acids.

It was communicated first to Dr. Pitcairne, and by his means came into the hands of others. It was at length printed in the second volume of the *Lexicon Technicum* of Dr. Harris. Sir Isaac there says, I call acid, what attracts strongly, and is strongly attracted. He apprehends acid particles united to earth to be the composition of all salts. Even that the alkalis, which are usually treated as the opposites and antagonists of the other, he supposes to be only earth joined with an acid strongly attractive. But his opinion in these particulars we shall more distinctly inquire into, and explain in the course of these lectures, as we prepare the particular substances to which these opinions relate.

But to proceed, besides these marks I have given to distinguish between acids and alkalis, there are other methods made use of to discover them. Sometimes an acid or alkaline quality lies hid in a subject so as not to manifest itself very distinctly to the senses, by the forementioned direct trials; yet will produce such effects, as more manifest acids and alkalis are known to do. One of these effects is the change, they occasion in the colours of many bodies. Syrup of violets, is commonly made use of in these trials. Acids turn its blue colour

lour into red, alkalis change it to green. But Mr. Boyle recommends above all the tincture of *lignum nephriticum*.

If cold water be poured upon a few shavings of this wood, it soon acquires a tincture, which looked upon appears blue, but seen through appears red. This blue tint is taken off by an exceeding small quantity of acid, even when the tincture is made very deep. For this reason Mr. Boyle recommends it as the most subtle criterion of acidity. Alkalis heighten the blue tincture.

(Here the experiments with syr. viol. and tinct. lign. nephrit.)

No other spirits, besides those which are acid or alkali, have been much considered in chemistry; except only the inflammable vinous spirits. Mr. Boyle has made some mention of other spirits, and calls them neutral.

Neutral salts are commonly known; such is common sea-salt, we use at the table; such also is salt-petre, the largest ingredient in gunpowder.

Inflammability is a property, which belongs to no spirit, except the vinous spirit; but all oils are possessed of it. This so remarkable a property of these fluids, while water on the contrary

trary is a potent extinguisher of fire, deserves particular consideration.

It has been observed before, that all bodies, when heated to a certain degree, emit light and shine ; water can never receive so great a degree of heat. The heat it has, when boiling, is the greatest, the most intense fire can give it, and with this heat it flies away in vapour. This property of water, of being incapable of any great heat, is that, which enables it to extinguish fire.

It has been observed in a former lecture, that heat diffuses itself from the hot body, and decays gradually. That it never stops short, and is interrupted at once ; inasmuch that the near approach of a cold body to a hot one necessarily diminishes the heat. For this reason, when cold water is thrown upon a piece of hot metal, or a burning coal, the heat of the body is necessarily lessened, till the water is by degrees heated and thrown off in vapour. But since water can receive but a small degree of heat ; if, as fast as the hot body dissipates the water thrown upon it, fresh water be supplied, the body must at last be reduced to the heat of boiling water only. But with this heat no bodies known, except the phosphorus from urine, will burn. Thus fire must be extinguished.

Oils

Oils are capable of receiving a greater degree of heat, than water is; infomuch that the steam, which rises from them, will emit light and shine; and when oil has acquired this heat, it will continue it, and consume away in a shining smoke or vapour; that is, the oil will burn.

It may be asked, why oil, when heated to this degree, should continue thus hot without diminution, till it is consumed, though no other fire be near it; whereas hot water, when removed from the fire grows gradually cool again. This is common to oil with all burning bodies, and they all require the presence of the air for this purpose. Any burning body in a close place, where all access of fresh air is excluded, soon is extinguished and grows cool.

There is another particular in the heat of burning bodies, which is likewise owing to the air. These bodies, like all others, grow gradually hot by the influence of the heat applied to them, till the instant in which they take fire. At that moment their heat increases many fold on a sudden. As they will not burn without the assistance of the air, so they never receive this sudden increase of their heat, if the air be absent, but will grow gradually hotter and hotter, as other bodies do,

till they come to the greatest heat, they are capable of.

Burning bodies do not all require the same degree of heat to set them on fire. Brimstone will take fire, and flame with less heat, than is required to fire oil, spirit of wine with less heat than brimstone, and the phosphorus made from urine, with much less heat than spirit of wine. And sometimes the bodies, that take fire with the least heat, are the hottest, when on fire. The flame of spirit of wine is hotter than the flame of oil; and the flame of the phosphorus from urine much hotter than either,

In short, bodies take fire by an action between them and the air, and a certain degree of heat is required in every body (though not in all the same) to excite this action. This action continues all the time the body burns. As soon as it ceases, or is diminished beyond a proper degree, the burning is extinguished. By setting a body on fire in a close vessel this action is discovered to have a very remarkable effect upon the air itself; for it is found to destroy the elasticity of part of it. If by an air-pump the air about the burning body is gradually rarified; or though the air remain equally condensed, as the body in burning charges the air with fumes, which mixt with it causes less and less pure air
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to be in contact with the burning body : in both these cases the burning soon ceases.

But in the open air, the air near the burning body being rarified by its heat becomes lighter than the rest of the air, and therefore must ascend, while its place is supplied by fresh air, which being rarified, in its turn also ascends. By this means a constant current of fresh air flows by the hot body.

There is but one other body known, which is possess'd of this property of the air, and that is nitre. This substance, we shall hereafter see, will make bodies burn, upon which the air cannot easily be brought to have any such effect ; and being an ingredient in gun-powder, causes that to take fire without the assistance of the air.

But what kind of action this is, whereby the air keeps bodies on fire, we shall see more distinctly hereafter.

As this action of the air is the only means found here upon the earth of continuing heat without diminution ; it is not improbable, that the sun is a body actually on fire, kept burning and in a flame by an air, which encompasses it. Perhaps the vapours arising in this flame, after circulating a time in the sun's atmosphere fall down, and become combustible again. If so, the sun will continue for ever burning without
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being consumed, The changes seen in the surface of the sun agree very well with its being such a burning body, nor is its density too great, being not above one-fourth of the density of our earth.

Thus I have endeavoured to give some account of the five kinds of substances, into which bodies are divisible by the fire. These are considered by the modern chemists, as so many principles, on which they build their reasonings.

Paracelsus and his train are more concise: they enumerate but three principles, salt, sulphur, and mercury; by the first meaning whatever is fixt, by the second whatever burns, and by the third all that is volatile; which Paracelsus illustrates after this crude manner, in wood on fire, what burns in it is sulphur, the smoke is the mercury, and the ashes the salt.*

But in regard to the five substances, which have been here enumerated, the great question, which occurs is, how far they deserve the name of principles. If by principles are meant the original forms of the particles of matter, by whose union in various proportions all compound bodies are produced, while themselves are neither alterable nor divisible by any natural

* Quod ardet, sulphur est; quod effumat, est mercurius; qui cinis relinquitur, sal est. Vol. i. p. 34. col. 1.

powers; these, we have here called principles, certainly deserve not that appellation; for they are themselves compound substances, and their constituent parts separable by chemical operations, as we shall see in the course of these lectures. But as the first operation of the fire in analyzing bodies divides them into some, or all of these substances; they are the first step in chemistry towards disclosing the nature of each compound: and what additional progress can be made in the knowledge of natural bodies must be deduced from examining and farther decomposing these.

Besides the five substances here mentioned, there is another produced from bodies, though not so much taken notice of by chemists. This is an aerial vapour, which, when purged from the heterogenous substances that rise with it, seems to be true permanent air.

I shall only add here, that the chemists have been many of them very confused injudicious writers, confounding the use of their terms without end. And thence some names in common use are not conformable to the definitions, I have given above. For instance, oil of vitriol, and oil of tartar per deliquium, are by no means properly to be called oils, for both will mix with water, nor is either of them inflammable.

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They are in nothing like oil, but in a little ropiness, which appears in them, as they are poured out of a bottle.

After this explanation of the general effects of the chemical analysis, at our next meeting, I shall proceed to consider composition.

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LECTURE V.

AFTER explaining the general effects of chemical analysis, and the principles of natural bodies, that discovers; chemical composition is next to be considered.

All mixtures of different bodies, fluid or solid; where their parts are mutually united, come under the present head. But the most eminent of these mixtures is, when a fluid is endued with a power of insinuating itself between the parts of a solid body, and uniting with them. In this action indeed the parts of the solid body are separated from each other, and therefore the body is not improperly said to be dissolved; but as the effect of this is to unite the parts of the body with those of the fluid, the action comes properly under the head of chemical composition. When the fluid dissolves the whole body, and receives all its parts intire within itself the operation is merely composition; but often the effect of such dissolution is more complex; and while one part of the body is united with the fluid, some other either flies off
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in vapour, or subsides : here there is a combination both of analysis and composition.

Every fluid, which has a power to dissolve other bodies, is called a menstruum. The operation of the menstruum is owing to some power, whereby its particles attract and adhere to the parts of the body, it dissolves ; the particles of the menstruum must likewise be in a disposition, that they can easily move toward the body to be dissolved ; and fluidity best fits them for this end. Pure water is a menstruum to all salts. And all the rest of the menstrua are no other than water impregnated with some active particles.

Sir Isaac Newton is of opinion, that wherever any dissolution is made, there an acid is present, if not manifest to sense, yet latent ; in which he only expresses his sentiment, that acid particles are the active principles, that attract other bodies, and are attracted by them. Thus he apprehends every kind of salt to be only an acid joined to some other substance. He chuses to call these active principles acid, because he supposes, that whenever they should be united with water alone, they will exhibit that taste. Though neither sea-salt, nor nitre has any acid taste, yet spirits very strongly acid are to be expelled

pelled from them, after which the remains will be a mere earth.

The greatest part of menstrooms are saline; spirit of wine indeed partakes of the nature of an oil, and its dissolving power chiefly consists in associating with itself, the unctuous parts of vegetables. Thus we shall see it dissolve resins, or the inspissated oils of vegetables, and extract them from the compound, in which they are lodged.

We have already observed, that the menstroom must have its parts moveable, that they may come readily in contact with the body, they are to act upon; and that this requires fluidity. In a fluid state, the active principles, while swimming in a liquor, easily move. By this means they readily approach the body, they are to work upon; and being in contact with it penetrate the body; the active particles of the menstroom insinuating themselves between the particles of the body, and carrying along with them part of the fluid, wherein they float, they disunite those particles: that is, they separate them so far asunder, till they can no longer act on each other, so as to cause a coherence. Then the particle of the body in dissolution is invested by the dissolving particles of the menstroom,
and

and carried away with them into the fluid. Thus the body, though heavier than the fluid menstruum, is suspended in it, so as to compose one fluid body with it.

It is here to be noted, that these active particles of the menstruum do not attract one another, but the other particles of the fluid, wherein they swim. Whence in the fluid they are dispersed equally throughout it, and, when they have dissolved a body, they in like manner diffuse the parts of that body uniformly through the menstruum.

When menstrua dissolve bodies, a visible motion is frequently, though not always seen in them, and bubbles filled with air rise in great plenty. This motion is called by the name of fermentation, a word first applied to that intestine motion raised in paste by the means of leaven in order to break the mucilage of the grain in the preparing of bread; but now by chemists is used generally for every kind of visible effervescence, such as is seen in mixing any fluid either with another fluid, or with a solid body.

Heat promotes the acting of menstrua. A menstruum, when heated, sooner dissolves a body, than when cold, and while hot, will retain more of the dissolved body, than it can hold afterwards, a part subsiding, as the men-

struum cools. Thus water will keep more salt or sugar dissolved, while hot, than it will retain, when grown cold again. Nay if care be taken to impregnate the hot menstruum with the body to a sufficient degree, the parts of the dissolved body, when the menstruum is become cold, will unite together again, and separate from the menstruum.

It is not difficult to conceive, upon what principle heat promotes the action of menstrooms. Heat dilates all bodies, and we also know, that by so doing, it diminishes the cohesion of their parts; for it not only quite separates the parts of many bodies, when it arises to a sufficient height, but universally in every degree renders bodies softer; thus fluids by heat become more liquid, and the most rigid solids diminish in firmness, till they become quite flexible, or even fluid. But as the action of menstrooms is to disunite the parts of bodies, we need seek no farther to know, what assistance heat gives to this action, than that it lessens the cohesion of the bodies to be dissolved.

As the action of menstrooms is promoted by heat, so the temperature of the menstruum is for the most part changed during the time of its acting, from what it was before. Most frequently the menstruum grows hot. In some cases

cases it grows cold. The like also is often observed in mixing fluids with each other.

To form some idea of two such opposite effects, let us consider, that as the action of heat is to expand bodies, and keep their parts at a distance ; so the action of a menstruum is to draw the parts of the body towards its own parts ; that is, while it operates to cause a contraction of the whole : and this being an action contrary to the action of heat, it is hence very conceivable, how cold is produced. To discover whence heat arises in these cases, it must be known, and shall hereafter at large be shewn, that there is one substance in all bodies ; by the copiousness of which in inflammable bodies, they are indued with the power of burning. We often shall call it the inflammable substance or principle : it is also usually called sulphur. Now sir Isaac Newton shews, that light, and consequently heat, operates immediately upon this part in bodies. We shall hereafter see, that in all visible fermentations a part of this is carried away in the frothy bubbles, that break through the liquor. It may also go off invisibly ; for when it goes off in the visible appearance of bubbles, another substance accompanies it. Such an agitation of the sulphur, as to expel part of it out of the body, must excite heat ;

this being the substance immediately operated on, and put into motion, when a body is heated. In this case therefore we are to consider two causes operating together; the forementioned contraction productive of cold, and this expulsion of sulphur, whereby heat is occasioned. When this latter operation prevails, the mixture grows hot.

Saltpetre and sal ammoniac (salts we shall hereafter take under particular consideration) mixt with water produce cold, mixt with strong spirit of vitriol produce a great heat, but the acid spirit may be so much diluted with water, that cold shall result from the mixture, though not in so great a degree as from mixing those salts with water alone. And in this case while a thermometer plunged in the mixture is affected with cold, another suspended over it shall receive heat from the ascending vapour, an evident proof that in this case both the causes before mentioned operate.

It is here to be noted, that as bodies are made up of particles, which are themselves composed of other particles; so these menstruums dissolve only the gross body, but not the particles which compose it. Their parts adhere together by a force not to be overcome by these powers.

Action

Action and reaction in all bodies are equal; therefore, when I here speak of menstrums dissolving bodies, I would not be understood, as if the power of dissolving ascribed to one of the bodies was a property of a distinct kind from the disposition to be dissolved attributed to the other. The dissolution is mutual, for the parts of both are removed farther from each other than before.

When a fluid acts on, and divides the parts of a solid, it is usual to say, the solid body is dissolved, and that the fluid is the dissolver. But indeed the effect in strictness is, that both substances become united, and as the fluid, by insinuating itself into the solid body, has separated its parts, and dispersed them throughout itself, so the fluid has its parts in some measure separated by the particles of the other body coming into it, and the result is a composition of the two substances into one.

Two things farther are to be remarked concerning menstrums. One is, that after they have dissolved any body, if another body, whereon they act more vigorously, be put into them, they quit the first body in order to lay hold of the second; so that the first body shall fall down, if it be heavier than the menstruum, which is the most common case, and is called precipi-

cipitation. If the first body dissolved be lighter than the menstruum, it will swim on the top of it. This not being a very common case has no particular name; but is in effect the same with the other.

Another particular to be here observed is, that when a menstruum by the assistance of heat has been charged with a greater portion of the substance dissolved, than it will retain, when cold, the redundancy does not always simply subside, but frequently gathers together in grains of some specific shape. And this manner of the dissolved body's separating from the menstruum is called crystallization; wherein to render the grains deposited large and in their most perfect form, some management is necessary. If the liquor is too strongly impregnated, the grains concrete together, and their true figure not easily perceivable. The most certain method is to dissolve the materials, which are principally salts, when pure water is the menstruum, in a large quantity of the liquid, and then to evaporate to a due degree.

The rule generally given for determining the proper degree of evaporation is to proceed with a gentle heat, till a skin, or in the more usual language of chemists, a pellicle appears upon the surface of the water. By this is known

known in most salts, when the hot liquor is so far impregnated with the salt, that a part will separate from it, when cold. In nitre this pellicle scarce appears. Those, who perform this operation upon nitre in large quantities, judge of the evaporation by the weight of the liquor; for the salt being a more ponderous body than water, the water, as it is farther charged with salt, becomes more weighty. But we may also judge when the liquor is disposed to shoot, by taking a little up in a spoon, and waiting till it is cold, and if the liquor be sufficiently charged with nitre, the salt will begin to appear in small threads. Sea-salt and borax, if the water be sufficiently evaporated, will shoot, while the water is hot.

This crystallization of salts is an operation, which greatly merits consideration. It promises no inconsiderable light into the nature of those powers, by which the small parts of matter act on each other.

If the least quantity of water be poured upon a parcel of salt, it will soon be dispersed through it; but the salt being a heavier body than water, the upper part of the wet salt will have more water among it than the bottom, the salt by its weight thrusting up the water.

If

If there were no action between the water and the salt, the water would be all kept upwards, and the salt lie at the bottom as compact together, as it did, before the water was put to it. But by the action, there is, between the parts of the salt and of the water, the water will take up some of the salt, and sustain it against the power of its gravity. If more water be poured on, more of the salt will be taken up, till at length with a due quantity of water all the salt will be dispersed through the water; insomuch that the lowest part of the water will scarce, if at all, be more impregnated than the very top. But for this effect there requires a certain quantity of water in proportion to the salt. And in different salts this proportion is very different.

With the heat which water will have in a moderate temper of our air, common salt requires less than three times its own quantity of water to keep it dissolved; nitre requires somewhat more than common salt; green vitriol scarce twice its own weight; but alum requires near seven times its weight of water; and borax twice as much.

As water, by a great heat, can be much more strongly impregnated with any of these

2 salts,

salts, than when cold ; so, when the water cools again, the overplus by its gravity will subside.

But the particles of the salt, when not kept separate by the water, have a power, whereby they approach and adhere to each other. Therefore, if the water be so far only evaporated, that this subsidence of the salt may be performed leisurely, the particles of salt will act so on each other as to unite in clusters, and form distinct bodies of a regular shape.

The colder the place is, in which the liquor is set, the crystalline bodies, into which the subsiding salt forms itself, will be the larger.

By the particles of the salt thus meeting together in regular shapes, it must be concluded, that before they began to meet, they were dispersed through the water at equal distances from each other. And this is a natural consequence of the action between them and the water ; for each particle acting equally on the water, one particle will encompass itself with as great a quantity of water, as the other. The most difficult enquiry in this case is, what causes the particular figure, into which each salt shoots. This must of necessity arise in general from this
cause,

cause, that the particles of the salts are of particular figures ; and that these salts on their different sides have different powers of acting ; for by this means these particles will meet on some of their sides only, but not on others, and so form the particular figures, into which we find them to shoot. It appears very surprizing, that the particles of matter should have such different properties on their different sides ; but sir Isaac Newton has evidently demonstrated this of the rays of light, so that the same thing may with less difficulty be admitted in other cases also, where there appears any proof of it. Whether this can be occasioned only by the figure or shape of the particle, will be best known, when we shall have gained a more distinct insight into the cause productive of this action between the parts of matter.

All that has been said of salts equally obtains in metals, which, when dissolved in their proper menstruums, are disposed to shoot out of them in some distinct form, after the same manner as salts do from water, and are then become a genuine salt.

A

COURSE of CHEMISTRY.

PART II.

On animal and vegetable Substances.

LECTURE VI.

BEING now to enter upon the particular processes of chemistry, it is proper to begin with the most simple.

The subjects therefore, I intend here to treat of, are to be inclosed in a suitable vessel, and exposed to the gradual action of simple heat only. The vessel, in which these subjects are inclosed, is placed in an open fire; that, before the operation is over, they may receive a great degree of heat.

The first subject, we shall consider, is animal substances.

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The animal substance most wrought upon by the practical chemists is hartshorn. They generally distil it in an iron pot, with a head fitted to it, to receive the vapours, and convey them into the receiver. It is also usual for them to place a glass vessel between the head of the still and receiver, to give the vapour (or in the language of chemists, the fumes) more room to expand in; and being carried by this means farther from the fire, they also condense the sooner. This vessel they call an adapter. When very large quantities are distilled at once, they place another adapter, made of tin, between the glass adapter and the head of the pot. For a small quantity of horns a coated retort, with or without an adapter, will suffice.

There is no other preparation used to fit this subject for distillation, but only to cut the horns small enough to be put into the vessel, wherein they are to be distilled. Nor is any thing mixt with them. The fire must begin slow at first, and be raised gradually, lest the vapour rising too impetuously, should burst the receiver.

When the distillation is finished, that is, when with the greatest degree of fire no more fume or vapour will ascend; we find in the receiver three different substances: a fluid, which will
mix

mix with water, therefore a spirit; another fluid, which will not mix with water, and will burn, that is an oil; also a dry substance dissolvable in water, therefore a salt. There remains behind a black coal, still retaining the shape of the horns. This coal, pressed ever so long in a close vessel with the most intense fire, will neither lose its blackness, nor its shape. But the blackness will soon be destroyed by a free admission of the air to it, as will be shewn in a following lecture. We do not prosecute our operations now so far, neither on this, nor on the other subjects of the present lecture; because we here intend only to shew the effects of simple heat, without the concurrence of any foreign assistance.

The spirit and salt are alkalis. Accordingly they turn the syrup of violets green. They give a disagreeable colour to all red syrups also; and therefore, when they are used in medical prescriptions, care should be taken not to add any such syrups, where this spirit is an ingredient.

This spirit and salt are the same, from whatever animal substance they are distilled; whether from harts-horns, vipers, or any other; also all the animal juices, as blood, urine, &c. afford the same. These spirits and salts may

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seem

seem to differ a little, when first distilled; because from some subjects they come more impregnated with oil, than from others; but in proportion as they are purified by the method, we shall describe and perform at our next meeting, they gradually discover a more perfect resemblance.

The principles hitherto treated of are found in every animal substance, whether solid or fluid; but there are some other productions peculiar to milk and urine, which deserve our notice.

Milk in boiling emits a watry vapour, neither of an acid nor alkaline quality, till such times, as what remains grows very thick, and acquires a great sweetness. Whence this sweetness takes its rise will be shewn hereafter.

If milk stands any time, it separates spontaneously into two parts, one of which is watry, and the other of a thicker consistence: they both in a little time acquire an acidity. But the acidity of the thicker part is owing altogether to some of the watry part remaining still with it: for if this watry part is well beat out, it becomes that oily substance butter. The watry part therefore is that only, which turns sour or acid.

The

The watry vapour, which arises from milk, will also by time grow sourish; for which reason the use of milk in distilled waters, directed in the writings of physicians, is with us wholly discontinued.

As milk is a fluid, that has for some time circulated in the blood vessels of an animal; so it begins to partake of the nature of the other animal juices: for though by standing it becomes acid, which happens not to any other animal juice; yet after fresh milk has been freed by boiling or a gentle distillation from its watry part; if it be then pressed with a stronger fire, an alkaline spirit will arise from it; and also an oil resembling the oil that comes from other animal substances.

Milk therefore appears to be reduced by the powers of digestion into a kind of middle nature between animal and vegetable substances; for as animal substances yield upon distillation the forementioned alkaline spirit and salt; so the greatest part of vegetables afford acid principles, as we shall see presently.

Hence it is, that milk is so very useful in hectic fevers; for milk approaching already so near to the animal nature, is easily converted into nourishment, and at the same time, by its having put off, as it were, but half its acid

quality, it is suited to cool the feverish heat, under which these patients labour.

In the next place, from urine is extracted that surprizing substance called from its perpetual shining in the dark phosphorus, and this substance also contains an acidity.

If urine be distilled, while fresh, it sends forth at first a watry vapour of the smell peculiar to urine. Afterwards with a strong fire it yields the same spirit, salt and oil, as other animal substances, But, if the urine be putrid, the volatile alkaline spirit arises from it with the first heat. The reason of this change in the urine by putrefaction, we shall discuss, when we come to take into consideration that grand operation in the œconomy of nature.

The phosphorus is obtained by distillation from urine putrified, by the force of a very vehement and long continued fire. The operation from the first invention of it has been kept, as a secret, till very lately in the Memoirs of the Academy of Sciences at Paris the process is described at large, which the describers assure us succeeded with them to their wish. The late Mr. Godfrey, with whom this secret remained, till the forementioned publication of it, informs us, that, if a quantity of the *fæces alvinæ* be digested along with the urine, a much larger quan-

quantity of phosphorus will be obtained, than from urine alone : also that the phosphorus cannot be obtained from any substance, but what has undergone digestion in an animal body.

The phosphorus melts, while under water, with a small heat, and by that means may be formed into any shape. If taken out of the water in the night, or in a dark room, it shines vividly, and a very small degree of heat sets it on fire. But it will not even shine, if covered from the air. While it shines in the air, it wastes in fume ; but in water, or in spirit of wine, it is preserved without diminution. No degree of heat will fire it under water, but if it be laid, when on fire, upon water, the fierceness of its flame will keep it up from sinking ; so that it will continue burning upon it, notwithstanding it is twice the weight of water. After the flame of the phosphorus is extinguished, the remains shew manifest signs of acidity ; the like are found, when a piece of the phosphorus has been left open to the air to fume away. The fume condenses into a very acid liquor. If, a piece of phosphorus being set on fire, a large glass be whelmed over it, white flowers will settle round the glass, which are very acid, and exposed to the air will attract a great quantity of humidity.

This substance is of no use in medicine. However it cannot but engage the attention of all, who have any philosophical curiosity, by its surprizing properties.

(Here the experiments with the phosphorus)

Thus we have found in two animal substances, the milk and urine, an acid part, which is not to be found in any other, except perhaps in an exceeding minute quantity. To discover whence the acid, here found, is to be derived, we must proceed to the other subjects of this lecture, which are vegetables.

Some of these produce upon distillation the same principles, as are afforded by animal substances. Of this kind are mustard-seed, horseradish, scurvy-grass, and all the plants, that have a sharp pungent smell and taste; also some others, as sponge and opium.

The analysis of these plants, is but a late discovery in chemistry. Mr. Boyle is the first, who mentions it.

Any of these vegetable substances distilled in the same manner, as described before, after sending out a fetid water, yield a volatile alkaline spirit and salt, together with a black fetid oil; leaving behind a black coal retaining still the shape of the vegetable, and not to be burnt to ashes without a free access of the air.

But

But the greatest part of plants exhibit productions of another kind.

Besides a water, that first comes over, we find here a spirit, without any salt, and also a fetid oil so ponderous, as to sink in the spirit. The spirit here produced is an acid one.

There remains behind a black coal, which always continues the same, how long soever it be pressed by the fire in a close vessel. And here the parts of the vegetable still hang together, as in the other subjects.

Charcoal is only this coal made from wood by a compendious manner of distillation. The wood is piled up endwise round a kind of funnel formed with sticks laid across each other, and then is covered close over with earth, with only small vents, that when the wood is set on fire, which is done by throwing some kindled coals into the forementioned funnel, it may burn as slowly as possible, till all the volatile parts are expelled, and the wood is reduced to this coal. Then the fire is quite extinguished by closing up the vents.

In the open air this coal, once set on fire, soon burns to ashes, which, contrary to the ashes of both the former subjects, contain a salt, as will be shewn hereafter.

The farther examination of the coal remaining in all our present subjects must be postponed, till we come to consider the effects of actual burning. But first we must examine a little farther the several substances, that have risen from our subjects. As these are expelled from a subject, wherein they all adhered united together, so now they are not yet perfectly separated; but each substance is left impure by a small mixture with the others.

The farther purification of these we shall refer to the next lecture.

But here it is farther requisite to take notice of one other substance, that arises from all the subjects of this lecture in distillation; which is an aerial vapour, that requires a particular artifice to collect it; in the method of distillation above described it is necessary, that the luting of the vessels may be so applied, as to permit this vapour to escape; otherwise the receivers will be blown off, or burst.

This vapour may be collected by the means of a retort having a long neck so bent, that it may open under a glass, inverted into water, the glass itself being also full of water. Then as soon as the retort grows warm, the air included within it will expand, and passing through the
pipe

pipe will rise up, and place itself in the top of the inverted glass ; and when the vapour issues from the subject distilling, it will follow the same course, and expel out of the glass as much water as is requisite to make room for itself. After the distillation is over, this glass will have received all the aerial vapour produced from the subject, and also so much of the air contained originally in the retort, as has been expelled out of it by its expansion. What this is may be discovered by exposing the retort empty to the same heat, and will never amount to four-fifths of the whole air of the retort by the greatest heat, that can be used. And thus may be known the quantity of aerial vapour, that is produced from any subject.

LECTURE VII.

IN my last lecture I began to describe the effects of simple heat on animal and vegetable substances ; that heat will divide and separate them into different parts. But as these do not at first come from the subject absolutely disentangled from each other, I shall now shew, how, by the farther application of heat only, a more perfect separation may be made.

To begin with the spirit, which in all these subjects is of a deep colour. This is owing to a small portion of oil still remaining in it. When this is separated, the spirit will be transparent and colourless like water.

The salt also found in any of these processes is foul with oil ; and is tinged by it of a brown colour ; when pure, it is perfectly white. I shall now therefore shew, how these spirits and salts are to be purified.

This may be accomplished only by distilling them over again with a gentle heat ; for thus the oil will either be left behind, or swim upon the spirit disentangled from it. One operation will not complete the work ; perhaps all the oil
can

can never be perfectly separated by this means, but by repeated distillations it may be so far diminished as not to be perceivable.

In these rectifications the heat of sand is commonly used, an open fire not being easy to regulate for so small a heat, as is here required.

The spirit and salt of hartshorn are excellent medicines; these therefore should be purified with much care. They may be mixt together, and distilled either in a glass body, or a retort, with the gentlest heat possible. The rectified spirit will flow into the receiver, and so much of the salt, as the spirit will not imbibe, settles in a dry form in the head of the body, or on the upper part of the receiver, when a retort is used. Some salt is commonly washed down, and lies under the spirit undissolved.

Since a large quantity of oil comes from the hartshorn along with the spirit; this must be separated from the spirit, before that is set to rectify: otherwise by swimming uppermost it will prevent the spirit and salt from rising.

The spirit and oil are separated by pouring them both together into a common funnel, first stopping the bottom of it with the finger. The oil will soon rise and swim upon the top of the spirit. Then the finger being removed the spirit
will

will first run out; and by timely replacing the finger, the oil must be prevented from following.

This is the general method for separating oil and watry liquors. If the materials are costly, a funnel of another shape is to be used. The body of this funnel is of a globular figure, with a small opening only at the top, which after the liquors are poured in, is to be stopt with the thumb or a cork. This opening being closed nothing will run out, though the bottom be unstopt. But when the liquors are separated, by opening the closure at top the undermost liquor may be let out; and, when that is all gone, the other prevented from following by closing the upper orifice again.

When the spirit of the present process is mixt but with a small quantity of oil, it is best to use the separating funnel now described, which will preserve the spirit from evaporating, while the oil is rising. When there is a large quantity of oil, it will soon cover over the surface of the spirit, that no waste by evaporation will happen in the common funnel.

In both funnels the separation will be quickened by having the funnel a little warm, and the mild heat of warm water is the fittest to warm the funnel with. But the warming of
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the funnel is most necessary, when the oil is costly. In this case, the liquors being put into the separating funnel above described, it is very convenient to set the funnel in warm water, till the oil is risen.

(Here exemplify the separation of oil and water by both funnels.)

But to return to our process, the spirit and salt of the hartshorn require more than one rectification, as has been said, to render them pure. By repeated operations, the spirit will become as clear as rock-water, and the salt perfectly white. However the oil adheres so tenaciously, that they are scarce to be totally freed. And though you rectify the spirit, till it appears ever so clear, or the salt, till it is as white as possible, yet in time they will contract a yellow hue, a sure token, that they are still charged with oil, which at first was so divided and spread through the salt and spirit, as to be invisible, but at length gathers together and appears.

These spirits and salts are much more agreeable to the stomach, when wholly free from their yellowness. Therefore, when they have changed colour, they ought to be rectified again, to fit them for use. This is too little practised, though these medicines would hereby

be greatly improved: when the oil is got together in such a body as to be visible, it will then also become sensible to the stomach, and often causes patients, whose stomachs are weak, to complain upon taking these medicines.

It required a strong fire to separate this salt first from the subject, but now it is once separated, it is so exceeding volatile, that it must be kept in a very close vial, or its most subtile parts will fly away into the air.

This great volatility of the salt gives the spirit an advantage in medical prescriptions; for should the salt be mixed with any powder, or even bolus, it would soon fly away, and leave the medicine destitute of any virtue to be expected from the salt: whereas, when the spirit is added to a draught, or the like liquid prescription, the spirit is easily confined by close stopping the vial, wherein the medicine is contained. It is true indeed, that the salt may with the same advantage be preserved by dissolving it in a liquor; but the spirit, being already a fluid, will more readily unite with the liquor, than the dry salt.

Every time this spirit is rectified, it becomes more and more impregnated with salt, part of the water being being left behind every time
with

LECT. 7. OF CHEMISTRY. III

with the oil. At length it will be so much charged with salt, that it will shoot, and sometimes even coagulate in the cold.

(Here shew some spirit and salt of hartshorn completely refined.)

When this spirit rises very pure; after the spirit will follow a water not discoloured with the oil, but scarce to be distinguished from common water.

Also from the spirit upon every rectification a quantity of dry salt will separate. Whence we learn, that the spirit is only water impregnated with this salt: accordingly, if this salt be dissolved in water and distilled, it produces the same spirit.

Thus we see, that this alkaline spirit is water impregnated with a particular substance, to which it owes its alkaline quality.

What has been said of the spirit and salt of hartshorn, may be equally applied to the spirit and salt of those plants, which produce the same with animal substances.

If the acid spirit produced from other plants be poured on chalk or coral, it boils up with it, and being distilled from it, comes over a watry fluid free from its acidity. That, which made it acid, it has left behind in the chalk or coral.

(Here shew this fermentation.)

It is remarkable, how inconsiderable a portion of matter contributes towards this acidity: for the weight of the liquor, by what it has left behind in the chalk, is scarce sensibly diminished. But this now left in the chalk or coral is alone the acid principle; all the rest of the liquor is no more than a fluid, wherein it swims. Why chalk or coral imbibes the acid from the fluid, it swam in, is not necessary here to inquire. It answers the present purpose, that we have a material capable of extracting this acid from the fluid. Mr. Boyle, who is the first, that put these acid spirits to this examination, observes, that, when the acid spirit is distilled alone with a very gentle heat, what rises at first will have little acidity; but be almost the same, with what is produced by the help of chalk or coral, which last was the medium he used. Herein this acid spirit differs from the alkaline spirit of the preceding subjects: for the first, that rises from that spirit, is the strongest; but here it is the weakest.

Though this spirit may be thus deprived of its acidity; yet it still retains properties, that distinguish it sufficiently from simple water. Mr. Boyle therefore calls this the neutral spirit of the subject.

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The oils of our subjects are next to be considered. These are more compounded substances than the spirits. We have shewn the spirits to be divisible by distillation into water and another substance, to which they owe the properties, that give them the denomination of spirits. The oils upon distillation send out into the receiver a quantity of oil in all respects like that distilled, except only, that it is more transparent and lighter; and with the oil in this rectification comes over, during the whole time, a portion of spirit, similar to that yielded by the subject, whence the oil was drawn. It is to be observed, that this spirit does not come out of the oil with the first heat, before the oil rises; but oil and this spirit come together to the very end of the distillation. After the distillation is finished, a dry black coal is left behind.

If the oil brought into the receiver be distilled again, it divides as before. This perpetually succeeds in like manner, how often soever the distillation is repeated; excepting that the spirit approaches nearer to simple water. The oil therefore is divisible into a black coal, and water, tinged at first with the spirit of the subject, whence the oil is drawn. These will not mix together again, and recompose the oil:

the reason of this is, that besides these two visible substances there is another, which flies off continually in an invisible vapour, whose assistance is necessary to the composition of the oil. How to measure the quantity of this vapour, and make some discovery of its properties, will be shewn hereafter.

A thick balsamic juice naturally runs from many plants, such as fir, yew, box, and the like. All the evergreens abound with these balsams, by which they are defended from the winter's cold. These are usually distilled with a less degree of heat, and in distillation divide just as the oils do.

This is largely practised in turpentine. It may be distilled in a retort, if it be first made a little warm, that it may be poured through a funnel into the retort without soiling the neck. This retort may commodiously be set in sand, and a small fire applied at first, and increased gradually afterwards. At the end of the operation, will be found in the receiver a quantity of oil and an acid spirit. If the operation be stopt, before the turpentine is dried to a coal, a transparent substance remains, brittle when cold, though melted with a small heat. This is called colophony or black rosin. The oil, that first distils over, is finer, than what follows : and
by

by redistilling the oil, it may be obtained yet finer. This oil, when brought to a great degree of fineness, is called the etherial oil of turpentine, and often, though improperly, the spirit of turpentine.

The thick substance remaining, after distilling from the oil its fine ethereal part, is called the balsam of turpentine.

The finer part of the oil will rise from the turpentine with the heat of boiling water and less; those therefore, who distil great quantities of turpentine to obtain the fine oil, distil it in a copper still with water, after this manner.

The turpentine being put into the still with a large quantity of water, the water is made to boil, and the vapour is condensed by passing through a worm-pipe encompassed with cold water, after the manner I formerly described, when I spoke of chemical vessels. The oil comes over with the vapour, and is separated in the distillation by a glass of a particular contrivance called a separating-glass, the form of which, and its manner of working we shall by and by see.

What is left of the turpentine, when all is drawn from it, which the heat of boiling water

will raise, is, when cold, of a brittle consistence. This is yellow rosin.

Turpentine distils from the tree while growing, from wounds made in it for that purpose. While the tree is burnt, a coarser juice runs from it. This is tar.

The method used for making tar is this. They make a floor with clay, or the like stiff earth, with a little declivity toward one part. Upon this they heap a pile of wood, and cover it with earth, as in making charcoal; leaving a small vent only, that the wood may burn slowly. During the wood's burning, the tar runs away, directed by the declivity of the bottom.

In the latter part of the operation, the tar becomes coarser than at first. This they convert into pitch in this manner. It runs into its receptacle so warm, that by the application of a live coal it will take fire. They set it thus on fire, and suffer it to burn, till it is brought to a consistence, which will harden, when cold. Pitch is also made by boiling tar to a just consistence.

The fine oil of turpentine is not the only one, for obtaining which boiling water is employed.

It is to be observed, that there are in plants two kinds of oil. One enters the composition

of the solid parts ; another is lodged in certain vesicles or cells fitted for its reception, after the manner as the fat of animals is collected within the cells of the *membrana adiposa* : and there are methods of separating this latter oil, without any mixture of the former.

Some of these oils will rise with the heat of boiling water. In this case the plant is put into a copper still with water, and the oil distilled from it in the same manner as in turpentine.

These oils, partaking much of the flavour and sensible qualities of the plant, are called the essential oils of the plants, whence they are drawn.

They agree in their medicinal virtues more with the plant, they come from, than any other chemical production does with the subject, from which it is extracted. Indeed as they are drawn with a small degree of heat, so they exist in the plant almost, if not quite in the same form, as that they came over in.

The greatest part of these oils are lighter than water ; but that is not the cause of their rising with so small a heat ; for some of these, such as the oils thus distilled from many spices, are heavier than water ; but the volatility of these oils is owing to the subtle spirit lodged

in them; for all these oils have a pungent smell.

The oils of other plants, where this volatile spirit is wanting, though they are much lighter than water, will not be thus separated. But these are obtained by pressing the subject between two iron plates. If the plates be a little warmed, more oil will be extracted; but, if they have given to them any considerable heat, the oil expressed will soon turn rancid. This is the reason, that physicians always prescribe these oils *sine igne expressa*. The safest method to liquify the oil, and facilitate its flowing from the subject, is to soke the subject a little while in warm water.

The seeds of plants, that abound with oil, are the only proper subjects for this operation.

In distilling the essential oils as before described, the vapour, which brings over the oil, is also in some measure impregnated with it, and therefore the water itself appears of a milky hue, and partakes of the smell and taste of the oil. We have asserted of oils, that they do not mix with water. But here the subtile spirit, which renders these oils volatile, communicates itself largely to the water, and retains with it a small portion of the oil. For this reason, in distilling these oils, it is most profitable to make use of
the

the water before employed in distilling the same sort of oil, for this water being already impregnated, will imbibe much less of the oil, than fresh water would do. It is also advantageous to set the subject, to be distilled, to macerate some time in the water kept warm, before it is drawn off; for by this means the subject is softened, and will part with more oil than otherwise it would do. The distillation may be so long continued, till the water shall come off acid; the moment this is perceived, the operation must be stopt; for this acid will not only prejudice the flavour of the oil, and of the preceding water; but may chance in its passage to corrode the copper alembic, and give them an emetic quality.

There is another method of obtaining from plants a water endued with the flavour of their oil. This is not now much in use; but it is performed by the cold still described in a preceding lecture. In this method fresh plants are distilled without any additional water. But here the watry part of the plant is caused to ascend, impregnated with the flavour of the oil. This process of preparing distilled waters being very tedious is much out of use.

It is necessary for physicians to know distinctly, what plants impregnate the watry

vapour with their virtues, and what do not. The ignorance of this has occasioned great absurdities in medical prescriptions. The only plants, whose distilled waters are of any efficacy, are those, from whence an essential oil may be extracted by distillation with water. In other plants the distilled water differs little, from what comes immediately out of a pump, or a river.

In like manner, when any animal substance is boiled in water, the vapour, when collected, differs in nothing from pure water, but in the smell, which is like that, we have in broth. If the boiling be long continued, this smell becomes fetid. But the water has acquired neither colour nor taste. This shews the mistake of those, who have expected great medicinal virtues in waters distilled off from animal substances.

As some of the oils of vegetables are volatile in the manner now described; so also are some resins from the same cause. From the gum called benjamin sublimes with a small heat a volatile resinous part in the form of white flowers. Camphire, as brought to us from the East, is wholly volatile, except what feculencies may remain in it. With a very small heat it may be sublimed into flowers; and by the use
of

of a vessel before described, called an infernal glass, a greater heat may be used, so that the camphire shall fix on the upper part of the glass in the consistence of a solid cake; and this is the way, wherein camphire is sublimed to purify it for sale.

We have thus now gone through the analytical processes usually performed by chemists on animal and vegetable substances by simple heat only.

LECTURE VIII.

HITHERTO I have considered no other use of the fire than by heating the subjects under examination in a close vessel, by which the effects of pure and simple heat upon these substances are seen.

As heat dilates and rarifies all bodies whatever; so these being heterogeneous, do not expand uniformly, and the different substances, of which they are compounded, being some more freely rarifiable than others, are gradually separated from each other. A great part of the most solid of these subjects appear under a fluid form, when separated from the rest. We find common water to be the basis of these fluids. The spirits are only water impregnated with some active principle, and the oils divide into water tinctured with the spirit of the subject, whence the oil was drawn, and into a dry earthy part. The solid parts, into which these subjects divide, are of two kinds; one that will unite with water, another that will not.

In this analysis of these subjects we are to consider the heat as producing no other change in the
bodies,

bodies, than making a separation of parts before united. If it be asked, why then cannot we reunite them again? I answer, not only that the texture of these organical bodies is injured by this separation of their parts; but also, that, as besides the visible parts into which the body is divided, there is also another, that goes off in vapour, in this is carried away the vinculum, which held the parts together. What this vinculum is, and what its powers of action are, will gradually be made appear, in the course of these experiments.

All the subjects, I have treated of in my two preceding lectures, yield this vapour so plentifully, that in distilling them, were the junctures of the vessels to be absolutely closed, the vessels could not escape being broke.

The consideration of this aerial vapour is a new thing in chemistry. The diligent author of the Vegetable Statics has made many well-chosen experiments concerning this matter. Before him the subject had been but very superficially examined; though it is very worthy our attention; for by the assistance of some experiments to be proposed hereafter, it will give us no small light toward discovering the nature of the air we breathe.

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This vapour expands by heat, and contracts by cold, as the natural air does. It has the same specific gravity, and the same degree of elasticity, whereby it resists compression.

The quantity of this air, which arises from the substances distilled, is very remarkable. From hartshorn there arises one-seventh of its weight in air; which comes with the white fumes, and continues to issue forth to the end of the distillation.

From solid oak is to be raised one-fourth of its weight of air, and from other vegetable substances, it arises in greater proportion. From tartar is to be obtained in air one-third of its weight.

Oils upon distillation afford plenty of this air. It is remarkable in the distillation of oils, that the water or spirit, which we have already shewn to separate from them, does not rise singly, and come all of it in one part of the distillation, but during the whole distillation oil and this water rise together; at the same time air disengages itself from the oil. By this it should seem, that this air contains in it not only the instrument by which this water and the earth left behind were before inflammable; but that by which they were united together in the form of oil.

And

And hence it is also probable, that in the distillation of more compound substances, a part, if not all of the spirit, which comes from them, existed in the subject in the form of oil, out of which spirit is produced in the distillation by the air's disengaging itself.

And this collection and examination of the invisible vapour arising in distillation completes the inquiry into the effects of simple heat on animal and vegetable substances, in a close vessel. To finish the chemical analysis of these subjects we must proceed to examine, what farther operation the fire will have upon them in the open air.

We have seen all animal and vegetable substances reduced to a black coal by distillation, and this is the ultimate effect of simple heat only, except perhaps at length to render the whole volatile ; but, if fresh air be admitted upon the coal, while hot, another appearance is soon observed. The coal quickly loses its blackness, and for the most part falls to ashes, whereas before, under the strongest fire, it retains its original form.

By this we learn, that with the substance, which tinges the coal black, goes off the principle necessary to hold the solid parts of the coal together. The coal of all vegetable substances
falls

falls to ashes as soon as the blackness disappears. One or two animal substances, as the teeth and the hardest part of the horns, retain their figure, even after they are become white. All other animal substances fall to pieces like vegetable substances.

By this we learn, that the principle, whereby the parts of these bodies are held together, is different from that, to which the coal owes its blackness ; or at least that in the most compact animal substances a less portion of it, than what will tinge the coal black, suffices to continue some degree of cohesion. Which is the true cause will be better judged of hereafter.

The coal of vegetables, if once set on fire, will continue burning of itself, till reduced to ashes, without the assistance of any external heat, though the coal of the acid family of plants burns most vigorously. And from hence we learn further, that this substance, which tinges the coal black, is that, by which bodies are rendered inflammable. Before the conclusion of these lectures we shall see, that this principle, which renders all bodies inflammable, that are so, is found in all compound bodies whatever, and is the very same in them all, though all are not impregnated with so large a share of it, as to be rendered inflammable thereby.

by. The coal of some animal substances will scarce burn of itself without the assistance of external heat.

Charcoal is this black remains of vegetables, whose manner of making we have already described.

Again, the coal of those vegetables, which yield in distillation acid parts, leaves after burning in its ashes two different substances, that are separable one from the other by boiling the ashes in water. If the ashes of the other subjects are boiled in water, the water, when separated again from them by the filtre, brings away nothing from the ashes; but in this the water will be found impregnated with a salt. This salt is separable from the water by evaporating the water; for the salt will stay behind.

This salt may be obtained from plants, that yield it, without distilling them; by setting the plant, when dry, on fire in a clean furnace, and collecting the ashes; for these ashes will afford the same salt by being boiled in water. In all cases to extract this salt to the greatest advantage, it is proper to put the ashes, after they have ceased burning of themselves, into some proper vessel, and by a strong fire to keep them glowing hot, open to the air, for some hours.

This salt, when first extracted from the ashes, usually appears brownish; but by being exposed for a time in a due degree of heat it will become very white. This salt is an alkali, not volatile, as that from animals, but endures so strong a fire as to melt. If melted, or fluxt, for a considerable time, it wastes continually, and at length grows so subtle, that it cannot longer be contained in any vessel. During this operation it usually changes colour, first becoming green, and afterwards reddish; but these changes perhaps arise from sparks of coal, which accidentally fly into the melting pot. I think the pot may be covered so close, as to prevent this change, and these colours will burn out and return again. This salt has always a fiery taste, and grows by long continuance in the fire a very strong caustic, so as, when laid upon any part of the body, and covered close over it, to burn it like an actual fire. Therefore, when used internally as a medicine, it should not be too highly calcined. When white it is abundantly hot enough. This salt is found in all the acid plants: that extracted from wormwood is most used in medical prescriptions; but there is no difference at all in the salt, from whatever plant it be extracted. As the volatile animal salt is the same, from whatever subject it is distilled,

so

so this salt is in all vegetables, where it is found, the very same: though many have absurdly ascribed to these salts all the particular virtues attributed to the plants, whence they are drawn.

If this salt, after it has been melted in the fire, be dissolved in water, and filtered, it will leave a quantity of earth in the filtre. The like it will do, how often soever the operation be repeated. From hence we may learn, that this salt is an earth, which has some other substance united with it, by the intervention of which it dissolves in, and is united with water; which substance the fire at each melting expels out of some part of the salt.

This salt, as has been said, is very fixt, as the other of animals was found to be exceeding volatile.

These are the two alkaline salts, besides which there is not known any other. Nor do they appear to differ in any other circumstance, than that of volatility only; excepting, that the volatile salt cannot be kept so long in the fire, as to be so much freed from the adhering oil, as the fixt salt may; by which means the volatile salt will not dissolve in water quite so freely as the other.

This salt, extracted in the manner as has been described, is not perfectly pure. If it be dis-

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solved

solved in water, and set by in a cool place, a salt of a different kind will shoot from it. Some of the water being evaporated, more salt of the like kind will shoot. At length no more of this salt can be produced, and the water being wholly evaporated, the fixt alkali salt will be obtained pure.

The fixt alkaline salt, I have now under consideration, is not to be prepared, but from subjects, wherein both an acid, and an oil, or inflammable part may concur to the production of it. Of this we shall have a remarkable proof in preparing this salt from nitre or salt petre. To the acid it owes its power of dissolving in water, and to the inflammable part its melting. The more this oily or inflammable part abounds in it, the readier it melts. Tachenius proposes a method of preparing this salt by heating the plant in a pan or a pot covered over, so as to prevent in a great measure the access of air to it, and by this means a salt is produced more impregnated with oily parts, and much more easily fluxible, than when the plant burns more freely, as in the manner before mentioned of producing this salt.

These salts are made use of in great quantities in several trades, viz. by the dyers, soap-boilers, and the makers of glass. All these uses

we shall explain in the course of these lectures ; but here is the proper place for describing, how the great quantities are made.

These salts, according as they are more or less purified from the earthy and oily parts of the plant, go by different names. The salt called pot-ashes is thus made.

The ashes of wood are first boiled in water, till the water is strongly impregnated with the salt of the ashes. In this tincture, or, as it is usually called, lye, are steeped the stalks of beans, and such like vegetables, of a middle texture between soft leaves and firm wood, and from this carried to a hearth inclosed with brick work, and there set on fire : as they burn, the fire is kept up by a continual supply of the same fuel. As these parts of plants abound with salt, and are still more charged with it by soaking in the forementioned lye, the salt notwithstanding the earthy part remaining with it, melts and lies fluid at the bottom of the hearth, all the time the fire is kept up. These succulent parts of plants also abound with oily parts, whereby the salt thus prepared resembles most, that prepared after Tachenius's method before described ; and like that, melts in the small heat of these hearths. This salt is used by the soap-boilers, and by the dyers.

This salt is not so white, as some other sorts of it. The whitest is called pearl-ashes, and is made from the ashes of vegetables by extracting the salt with water, and then calcining it in a furnace like that, in which red lead is made, which we shall describe hereafter. The fire, by which this salt is calcined, is not attended with any expence; for the ashes of the fuel will serve to make more of the salt.

Thus I have described the result of burning, as far as relates to those parts of the plants, which stay, and endure the fire. Its effects upon the volatile parts are no less remarkable; for the foot, into which the smoke condenses, (though the plant be of the acid kind) affords upon distillation a volatile alkaline spirit and salt, such as simple distillation produces from the other species of plants: and the phlegm, which first rises, has the like fetid smell, as the water of the alkaline plants.

We shall find, that putrefaction produces the same change in these plants. But thus far burning differs from putrefaction, that in burning, though this volatile salt is found in the foot, yet the ashes retain a large portion of fixt salt, though not altogether so much, as when the plant has been distilled in a retort before calcination. In putrefaction, if it be permitted

to proceed, till it is become perfect, there is scarce any fixed salt left in the subject.

Now we have gone through the common analysis of animals and vegetables. In animals we have found a quantity of water plentifully lodged even in their dryest parts. This water we found impregnated with a volatile substance of an alkaline quality; the same substance we have seen likewise under a solid form. Besides these we had a thick oil and a black coal, which by burning becomes a mere white earth.

In some few vegetables, we found the same principles. And all vegetables after putrefaction, exhibit entirely the same substances as animals do. Otherwise the greatest part of vegetables, yield very different principles.

The, water which comes from them, besides a very pungent smell remarkable in it, is strongly impregnated with acidity. Two oils were also found in them. One separable from the solid parts; the other, which we called the essential oil of the plants, is chiefly, what is lodged in particular cells of the plant, and collected together there in the form of oil, while the plant is growing, just as the fat of animals is contained in membranes prepared expressly for its reception. Besides these parts extracted from vegetables, there remains a black coal, which

calcined falls to ashes; and in the plants, where principles are found analogous to those of animals, these ashes are a mere earth; in the others they contain a large quantity of a salt, which remains very fixt in the fire; whereas the salt found in animals, and in the other species of vegetables, is exceeding volatile.

This fixt salt is also an alkali, as well as the other, though it be found in plants, which abound with the acid principle. We mentioned, that this salt is only producible from subjects, wherein are found both acid and inflammable parts. Sir Isaac Newton was the first, who perceived, that these fixt alkali's were an earth with an acid adhering. To the acid in this salt (as has already been observed) is to be ascribed its power of uniting with water, and to the inflammable principle its melting in the fire. But its union with water is in part obstructed, while any gross oiliness remains in the salt; and the more effectually that is driven out by the fire from any of these salts, so much the more strongly does the salt draw moisture to itself. Insomuch that, when an alkaline salt is calcined very high, it draws the natural humidity of the air so potently, that it is difficult to keep it dry. However we have found, that at length the principle, which unites the earthy
part

part of the salt with water, will be also expelled by the fire.

The oils of all these subjects we have found to be a union of two substances, earth, and water a little tintured with the spirit of the subject. We must farther observe, that so much of the oil, as is thus divided, has lost its inflammability; and we have just described a process, whereby it appears, that during the distillation an invisible substance escapes under the form of an aerial vapour. In this substance therefore we must seek for the principle, whereby the oil is rendered inflammable. Therefore as the coal both of animal and vegetable substances is an earth joined to an inflammable principle, so the oils of these subjects are a composition of earth, and water tintured by the spirit of the subject united with the like inflammable principle.

LECTURE IX.

TH E nature of the principles, into which bodies are reduced by the fire, will be best understood by the effects of two natural operations, the fermentation incident to vegetable juices, and the putrefaction common both to vegetable and animal substances.

Fermentation is a change, which ripe juices are disposed of themselves to undergo, whereby an intoxicating spirit is first produced, which was not before in the plant, and at length the fermentation ends in vinegar.

This fermentation is properly an action between the acid, and the other parts of the juices, principally their oil, whereby the oil is attenuated, and so united with the acid, as to be dissolvable in water: in the mean time it retains the inflammability proper to oil; nay has increased it. But at length the acid so far prevails, that the liquor, now become vinegar, will burn no longer, but will quench fire.

A certain proportion and union between the acid and oily parts is requisite to promote this action of fermentation.

A due mixture of acid and oily parts produces sweetness.

Sugar will burn, therefore has received some oily parts from the juice, whence it is made, and upon distillation it yields an acid spirit. The like acid spirit is produced from honey, which is also an inflammable substance. This composition of acid and oily parts is that, which is most conducive to fermentation. For this reason we see the sweetest juices, as that of grapes, are disposed, when pressed out in large quantities, to ferment of themselves. On the other hand unripe juices, that have a rough austere taste, will not easily ferment. Also those, which abound with oil to such a degree, as to lose their sweet taste in a flat oiliness, and those juices, wherein the tart taste predominates, ferment but sluggishly.

Not only the expressed juices; but also the juices drawn from several parts of plants by infusing them in water, will also ferment, as we see done in barley in the making of beer.

But here the grain is first to be prepared, that the oily and acid parts may be so united together, as to produce the sweetness, we have observed to promote fermentation. The grain is first macerated sometime in water, then the water is separated from it, and the grain laid in heaps,
till

till it begins to grow : after this it is dried with a gentle heat, and the grain is found to have acquired a saccharine sweetness.

When a vinous liquor is to be made of this grain, water of a somewhat less heat, than that wherewith it will boil, is to be poured upon it. The common test, I think, for the heat of the water, is to wait, after it has once boiled, till the steam is grown small enough not to hinder the water from making a sensible reflection of the person, who looks upon it. When the grain has stood infusing some time, the liquor is strained off, and, when cool, mixt with some material proper to quicken the fermentation.

In the making of wine, that juice ferments usually without help ; the only operation it undergoes, previous to its fermentation, is in the rendering the wine red. There the juice is two or three times successively infused upon and pressed strongly from the husks of the grapes, which are of the red kind ; and from these husks the wine receives its tincture.

Fermentation proceeds thus. The fermentable liquor being put into a vessel in a place moderately warm, it soon begins to swell, while bubbles break from it, and a whitish frothy head forms itself over it. This head at length condenses

denfes and finks, and becomes the lee, the fermentation ftill continuing. From this time the vinous fpirit leffens by diffipation, and the fermentation being kept up terminates in vinegar. If the liquor, as foon as the white head finks, be drawn from it, and put up in a clofe veffel, the fermentation will be checkt, and the liquor will remain for a long time in the ftate of wine. But wine is continually changing, though by flow degrees, till at laft it ends in vinegar. The genuine part of the wine-cooper's fkill is principally to refrain the progrefs of the fermentation, as long as poffible, but at length no art can prevent it.

All the time the liquor is in the ftate of wine, an obfcure fermentation proceeds, whereby it acquires more fpirit, and continually deposits lees. Thefe lees keep up the fermentation, and when ever it grows too ftrong, the moft effectual ftep to check it is to draw the wine off from its lee.

The wine, during this ftate, likewise continually deposits a faline cruft, which adheres to the fides of the cask containing it. This faline matter is called tartar or argal. At length the wine deposits the moft part of the oil in the form of a mucilagineous fediment, and then becomes

comes vinegar. Thus when wines turn ropy, we know they are very near being sour.

Only the juices of the acid species of plants ferment, the juices of the alkaline plants putrefy.

It has already been mentioned, what these fermentable juices yield upon distillation, before they are fermented, viz. an acid spirit, oil, and a black coal, from whence a salt may be extracted by burning it in the open air, as from the remains of all the acid family of plants. When wine is distilled, the first thing which rises from it, is a very volatile subtle fluid, of a very peculiar kind. It will mix freely with water, and yet burns like oil, nay with a much fiercer heat. This spirit is not only exceeding volatile, when separated from the wine; but also rises from it with less heat than, what would raise any thing from the juice before its fermentation.

This spirit rises mixt with much water, from which it may gradually be separated more and more, by subsequent distillations in tall glasses, and with a very gentle heat: as it is more and more freed from its aqueous parts, it increases greatly in volatility.

(Here explain the manner of taking the proof of spirits.)

This

This spirit being well freed from its watry part, it burns all away, when once set on fire, without leaving any remains behind whatever. If it be burnt under a tall vessel, so contrived as to collect the vapour, which rises from it in burning, that vapour is found to be mere water. Hence we learn, that this spirit is water united with that subtile part of the oil, from which oil receives its inflammability, and which we shewed in the last lecture to fly from it by repeated distillations.

Hence we may learn also the cause of what is observed in the distillation of honey and sugar, which Mr. Boyle was at a loss to explain, that though these substances are inflammable, yet they yield scarce any oil upon distillation; for as these substances contain only that portion of the oily parts, which is convertible into spirit, so by distillation we find, they contain no more oil, than what loses its form in one distillation, by the dissipation of the subtile part, to which its inflammability, and the form of oil are owing.

After all the forementioned spirit is distilled off from the wine, the remains yield the same principles, as the juice would have done before fermentation.

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When the liquor approaches towards vinegar, it yields again less inflammable spirit; inso-much, that when the vinegar is completely made, it affords none at all; but upon distillation the first liquor, that rises, is an uninflammable acid spirit; and by continuing the distillation, the more acid does the liquor grow, that comes off. At length what ascends, becomes oily, but still is acid, as will also the remains be. These remains burnt in the open air yield a salt of the same kind as that, which is producible by burning from all the plants, that yield acid principles in distillation.

If tartar be distilled, it produces no inflammable spirit, but yields altogether the same substances as the acid plants afford; that is a pungent spirit impregnated with acidity, an oil, heavier than water, with a very small portion of a light oil and a black coal, which being set on fire in the open air yields also the forementioned salt.

By this distillation of tartar we see, that it contains those parts of the juices in which the fermentation has made no change, being only deposited from time to time from the other parts of the juice, whereon the fermentation operates.

Such

Such a saline substance, as this, will separate from the juices of plants without their fermenting. It may be produced in the following manner. After the plant has been bruised, and the juice pressed out; the juice is to be set by for some time to settle: after which let it be strained, that the liquor may become clear, and then be evaporated over a gentle fire to the consistence of a thin syrup. Let the juice thus prepared be set in a vessel in a cool place, and at length a salt will settle about the sides of the vessel, while a feculency subsides to the bottom. An unglazed earthen pan is the fittest vessel for this purpose, that the salt may be assisted in its adhesion by the roughness of the vessel. The liquor must also be covered over with clean oil to keep it from the contact of the air. Otherwise the juice will not be preserved, but be changed by fermenting or mouldiness.

These saline substances are usually called the essential salts of the vegetables, whence they are produced, and tartar is very properly to be called one of them.

Tartar dissolves in water with difficulty, and will not remain dissolved in it, unless the water be almost of a boiling heat. As soon as the water is cold, the tartar almost intirely quits it again, the earthy part subsiding, while the saline

part shoots on the bottom and sides of the vessel, and a small saline crust swims on the top. This crust on the top is properly called the cream of tartar, and the shootings, the crystals; though these also, which, differ nothing from the other, but in the place, where they are collected, are generally comprized under the name of cream of tartar.

In preparing these crystals, the tartar should be boiled in much water.

When the tartar is first dissolved, the water appears very dirty; and the crystals separate so soon, that they do not admit of so slow a filtering, as would be necessary to purge the liquor intirely from this dirt. It can only be strained through a cloth. But when the crystals are shot, as they will not dissolve in cold water, what dirt has passed the strainer, and remains loose among them, may be washed away by the affusion of cold water.

Thus may the tartar be freed from its gross earth. But the intire purification requires a particular artifice. It is done after the tartar has been separated from its gross dirt, as now described by boiling it again with a small quantity of a certain earth, which will not render the tartar much more dissolvable in water; but yet separate from it a sufficient portion of its oily
and

and terrestrious parts; from which it receives its brown hue.

The distillation of tartar makes manifest, why it dissolves in water with so much difficulty; for that shews the tartar not to be a simple salt, but to have a great redundancy of oily and terrestrious parts joined with it.

Tartar, and the other called essential salts, are so named, because they are supposed to exist in the juice of the plant, as they appear to us. But they rather seem to be produced from the liquor by a new combination of parts; for at first the whole of the juice will more easily dissolve in water than these salts.

After this description of the effects of fermentation, we may judge in some measure, wherein this remarkable operation of nature consists. When this operation has proceeded in full vigour, we find, the acid has so far disengaged itself from the other parts of the juice, as to manifest itself more conspicuously, and pure, than it can be obtained by any other means. But of all the parts of the plant, the oil is more particularly affected by this fermentation. It is no sooner begun, but the quantity of oil is diminished, and in its stead an inflammable spirit produced, which will mix with water. It appears therefore, that the inflammable part of the juice,

or its oil, is so dissolved and united with the acid, as to be capable of mixing with water. By a longer action of the acid, when the liquor becomes vinegar, the oil is then so much farther altered, as to lose even its inflammability.

When the liquor is drawn from its gross lee, and closed up in a cask, before the fermentation is finished, it proceeds then slowly. But however by the liquor's gradually depositing some of its earthy and oily parts in the form of tartar and lee, the acid at length will so far prevail as to carry on the fermentation even in a close vessel, till the liquor becomes very sour.

This fermentation (by the wine-coopers commonly called fretting) whereby the wine runs to vinegar, is usually considered under the notion of a second fermentation, as if it were an action of a distinct nature from the first; but I apprehend, this is no otherwise a second fermentation, than because the first part of the fermentation has been restrained by art; since, if the fermentation was sufficiently strong at first, and not interrupted, the liquor, after a time, heats, the inflammable spirit is dissipated, and the fermentation ends in vinegar, before it ceases: nay sometimes, in very hot weather, the distillers find, to their great loss, that no art can stop it sooner.

It is usual indeed, when it is desired to make vinegar of wine, to promote the acetous fermentation by art, mixing the wine with its own lees, with vinegar, or with tartar; or putting the wine into a cask, that already has held vinegar; and other the like means will produce this effect.

Likewise, when the fermentation at first proceeds too slowly, it may be promoted by art. Such juices, as ferment but heavily, may be quickened by adding such as have a greater facility in fermenting.

The juice of grapes, hindred from fermenting by impregnating it with the smoke of sulphur, put to wines, will excite a fermentation in them. This is made use of by wine-coopers, when they mix different wines together; for unless the wines after mixing ferment, they will not unite into one uniform taste. Other materials are too often made use of for this purpose, which clog the wine, and make it disagreeable to the stomach; but this being a vinous juice is no prejudice to the wine. A little of that head, we observed to rise upon fermenting liquors, will gradually promote fermentation, being generally used by the brewers for that end; and it will do the same after it is subsided, and become lee. All the purgative resins will likewise pro-

mote fermentation. Jalap is most used by the distillers, because it gives no taste to the spirit.

On the other hand a mixture of acids or alkalis, so as to destroy that balance between the acid and the rest of the juice, which is most conducive to fermentation, will give a check to it. The spirit distilled from wine checks fermentation very powerfully. These spirits are one pernicious ingredient in all adulterated wines; for when heterogeneous materials have been mixt together, which would fall into a violent fermentation, it is necessary to add a large quantity of spirits to restrain it.

Why this spirit is so powerful a restrainer of fermentation, is the result of the effect it has upon acid spirits. The fume of sulphur acts upon the same principle, and is often used for this purpose.

Upon the whole, we see, that the last effect of fermentation, is for the acid to operate upon, and prevail over all the other principles.

The unfermented liquor, called must, is sweet. There the acid is intangled with the oil so much, that it can only affect the tongue and palate in the mild and agreeable manner, we call sweetness. In fermenting it attenuates the oil, by which this sweetness is gradually lessened, till at length in vinegar it discloses
its

its genuine taste, when disentangled from those oily and terrestrious parts, which disguise it.

From the distillation of vinegar we may learn, how firmly acids can adhere to other bodies: for here the acid in distillation accompanies the volatile parts, and ascends with them, and also keeps joined to the more fixt.

(The calcination of tartar.)

Here in vinegar we find the vegetable acid in its greatest perfection, and produced without the assistance of any chemical fire.

Thus by fermentation we see the same acid separated from vegetables, as by distilling them.

By putrefaction the volatile spirit and salt are so separated from the rest of the compound in animal substances, that it may be obtained entire by no greater heat, than what is necessary to sublime it. When those substances are distilled fresh, a great degree of heat is necessary to disunite the volatile spirit and salt from the other parts. But by putrefaction they are so disengaged from the rest, that they are separated, and brought to view by no greater heat than what will sublime these substances, after they have been extracted from the mixt. Therefore putrefaction alone has truly produced these substances out of the compound.

Thus we find by the two natural operations of fermentation and putrefaction the same substances produced out of mixt bodies, as are expelled from them by the heat of chemical fires.

Putrefaction will produce these volatile spirits and salts from plants also, even from those, whence the simple and unassisted heat of our fires produced only acid parts. Though it appears in the distillation of soot, that heat assisted by the air, will dispose these substances also to afford the like.

The leaves, and such succulent parts of all plants, if laid and pressed close together in a heap, when green and in a warm place, soon begin to putrefy. They first grow hot, even sometimes to the taking fire, and at length turn into a pappy consistence, which being distilled yields a spirit stored with volatile salt, to be drawn from it by rectification; and when this rectification has been repeated two or three times, the salt appears to be altogether the same with that, which comes from animal substances.

When the distillation is finished, what remains in the retort is a great deal less, than it is, when the plant is distilled, before putrefaction. The volatile salt also is much more in quantity, than
the

the fixt salt to be drawn from the plant not putrified would be.

From plants thus putrefied there also comes off a black but light oil, resembling that drawn from animal substances.

In the last place let it be observed, that in this putrefaction all the appearance of the acid is lost.

It is also very remarkable, that the earthy part is much diminished. It seems therefore, that the earth of the plant is partly turned into volatile salt. Let us also consider, that the acid of the plant is now lost; and we shall see here an effect consonant to sir Isaac Newton's opinion of alkaline salts; for where is this acid retired, but into the other parts of the plant? In a word as fermentation is an action arising in the juices of plants, whereby the acid disengages itself from the other principles so far as to unite more copiously with the watry part of the juice, whereby the acid manifests itself more than before; so here in putrefaction the earthy parts imbibe the acid so as to render it invisible.

We see also operating in the same plant both the fermentation, which ends in vinegar, and putrefaction productive of alkaline substances. The intestine motion; which arises in the juice, where watry and acid parts abound, produces

vinegar, and in the plant itself, where its earthy parts exceed, the intestine motion causes putrefaction.

In the next place we learn from hence the nature of animal digestion; for here we may see, that the putrefying of vegetables works the like changes in them, as digestion does, when it converts them into animal substances: digestion therefore is, as it were, a begun putrefaction.

For this reason, the substances, from which we receive nourishment, are such as are disposed to putrefy; and those substances, which putrefy soonest, soonest digest. Meats of hard digestion are rendered easier to digest by keeping. If they are kept so long as to be actually putrid, they are then indeed become unfit for nourishment, because they are got beyond the state, which the action of the stomach and bowels is to bring them to: digestion in the stomach is no more than an advance toward putrefaction; for we find, that vegetable diet, when in the blood, does not immediately part with its acid nature, which is the cause of that acidity, we observed to be in milk.

The firm union with the acid and terrestrious parts brought about in putrefaction, and in animal concoction, whereby vegetable substances become part of an animal body; is the reason, why

in the oil of putrid vegetables, and in animals no visible acid is found, as in the other oils of vegetables. Here the acid is too strictly united to the earthy parts of the oil to be expelled from thence, and manifest itself. In other words it now adheres more firmly to the earthy than to the watry part of the oil.

In fermentation the action of the acid is to cast off the grosser terrestrious part from the rest of the juice; but here the action of the acid is to unite itself more firmly to the earthy parts of the vegetable, and at the same time to attenuate and render more subtle those terrestrious parts.

LECTURE X.

HAVING gone through the usual chemical analysis of animal and vegetable substances, the recompositions of those substances, which have been contrived from them, whereby very valuable medicines have been introduced, and the nature and properties of those several substances illustrated deserve next to be considered.

Of the processes therefore I now propose particularly to consider, the first is the property of the lixivial salt extracted from the ashes of vegetables to run into a water by attracting the moisture of the air.

If a lixivial salt be highly calcined, it will scarce be cold, before it becomes damp, beginning to dissolve by the moisture of the air.

But all such salts, if hung up in a bag, or laid upon a glass, will soon imbibe so much moisture from the air as to run off in a liquor. This is the most effectual way to have the salt pure from any earthy part: for thus more earth will be left behind, than when it is filtered through paper.

This

This property of lixivial salt makes it very useful for rectifying spirit of wine ; for if as much of this salt as amounts to about one third of the spirit be added to it, and then the spirit be gently distilled, it will rise much freer from the phlegm, or watry part, than otherwise it would do ; the phlegm being held back by the salt, this salt being dissolvable by the water, but not by the spirit.

It must here be noted, that some salts are dissolvable both by water and by this vinous spirit ; others by water only. Of this latter kind is the fixt alkali, or the lixivial salt here under consideration, unless, perhaps, some very subtile and invisible parts of it, by which the spirit may be rendered by digestion with this salt somewhat more pungent. If the alkaline salt by melting has acquired a reddish hue, the spirit will receive a similar tint from the salt. But this colour more properly arises from that, which coloured the salt, than from the salt itself.

When this fixt alkaline salt is mixt with any acid, it suddenly excites a very visible fermentation : amongst the rest with the acid of vegetables, which appears least intangled with other substances in vinegar, especially after the vinegar

gar has been distilled, and thereby its most unctuous parts separated.

If a little of this salt be thrown into vinegar, whether distilled or not, numerous bubbles, with a small hissing noise, presently arise, and the salt is soon dissolved. Upon throwing in more, fresh bubbles appear. At length no farther commotion will be excited by casting in the salt. And, if the salt be cast in with a careful hand, neither will any fermentation appear upon adding fresh vinegar. But if heat be applied, the salt will still ferment with an additional quantity of vinegar. Though, when about sixteen or twenty times the weight of the salt has been added of the vinegar, no farther fermentation will appear, though the vinegar boil. If this be done with distilled vinegar, and the operation prosecuted with the following circumstances a neutral salt neither acid nor alkaline will be produced very white. After the salt is so saturated, that no fermentation follows upon the affusion of more distilled vinegar, the liquor is to be evaporated away, when a salt will be left foul and black, especially if the operation be performed in an iron vessel. This salt is to be melted for a little time, which is done with a very small heat. Then, thrown into
2 water,

water, it immediately dissolves, and deposits its blackness ; the water being evaporated, with care that no more heat be used at last, than just what is sufficient to dry the salt, the salt will be left very white ; which must be immediately put up in a close glass, for scarce any salt attracts so powerfully the moisture of the air.

This salt has been called tartarus regeneratus, thought it differ sufficiently from tartar. In the present Pharmacopœia it is named sal diureticus, from its medicinal operation.

This salt is one of those, which dissolve both in water and spirit of wine ; and the criterion of its perfection is, that it dissolves in either without depositing any sediment. When rendered thus pure, the stomach bear a greater dose of it than otherwise.

If, when this salt is last dried, so much heat is used as to cause it to melt, it will concrete into a foliated texture. But with so much heat it is difficult to preserve its intire solubility.

This preparation is a valuable medicine. And there is an extemporaneous composition formed upon the same principles generally esteemed. This is the juice of lemons mixt with a fixt alkaline salt : it is most usual to join one part of the salt with about twelve parts of the juice.

Fixt

Fixt alkaline salt added to a solution of tartar or its crystals made in boiling water, produces also a kind of fermentation, of which we shall have more examples hereafter.

In the foregoing process we see, the fixt alkaline salt excite a fermentation with the vegetable acid, when joined only to water. In this we find, the same alkaline salt ferment with the acid lodged in tartar, and separate it from the earthy and oily parts of the tartar, and unite it with itself, thereby composing a salt dissolvable in cold water.

By this we see, that the same acid may act with different degrees of force upon different terrestrious substances. In tartar the union between the acid and the terrestrious parts is so great as to render the whole, except some grossest part of its earth, dissolvable in water, and when the water is not hot enough to retain the tartar suspended, the acid of the tartar still retains its adhesion to the other parts of that salt, so that almost the whole separates from the water without any disunion. But here the acid quits its own earth, to take hold of the alkaline salt, whereby the other parts of the tartar, which before were suspended in the water by the acid, are now in great part precipitated as earthy fæces.

The

The affusion of vinegar also upon many substances wholly indissoluble in water will raise the like effervescence.

By this effervescence with vinegar and other acids, these substances are usually ranked under the class of alkalis, by a name borrowed from a plant, which yields this salt plentifully. And under this head are ranged coral, chalk, oyster-shells, and all those called testaceous powders, all which excite this effervescence with acids and destroy their acidity. But all these substances are distinguished from alkaline salts by their not dissolving in water.

When distilled vinegar is poured upon coral an effervescence, as has been said, arises. If vinegar is thus gradually poured on, at length no farther effervescence will follow; but that the coral may be fully saturated, the mixture should be set upon warm sand, and stirred now and then, till the heat will raise no effervescence. The liquor being afterwards filtered, and so much of the coral as the vinegar has dissolved precipitated by a solution of an alkaline salt in water, the powder, which falls, is no longer dissolvable in water, and is called the magistery of coral. The liquor evaporated to dryness leaves behind a substance, that will dissolve in water, and is called the salt of coral. By this we may see,
that

that though coral is itself so much an earth, that it will not dissolve in water, yet the acid of vinegar, by uniting with a part of it, will render that part a true salt. Here therefore we have an instance of producing a salt by joining an acid to a mere earthy substance, wherewith it is disposed to unite.

How much this and other the like experiments conduce to explain the nature of salts, I purpose to consider farther hereafter.

LECTURE XI.

WE are now upon the compositions usually made from the substances, which our preceding analyses have afforded us; and we have considered the effects of compounding salts, and saline spirits. We shall proceed to the operation of salts on oils, and inflammable spirits, and the action between these subjects themselves.

Lixivial salts act strongly on oils.

Common soaps, both soft and hard, are made by uniting oil and tallow with a solution of some lixivial salt in water. But, as the soap-boilers take into the operation the assistance of lime, I shall defer the farther explanation of this, till lime shall come under consideration.

The soap of tartar, a preparation first produced by a necessitous quack, though since greatly celebrated, is an attempt to unite the alkaline salt of tartar with oil of turpentine. What oil can be joined with the salt will soon be taken up with the help of a little warm water, notwithstanding the tedious processes usually re-

commended for this end, attended with cautions, which in reality are no other than endeavours to retard the effect. The direct method is to melt the salt, powder it hot in a warm mortar, and put to it an equal weight of oil of turpentine also warmed, and while they are rubbed together, adding about half the weight of hot water. They will soon unite, though time is required for the composition to acquire a due consistence. This salt is said to be capable of imbibing thrice its weight of oil. But from the soap of tartar after distillation and calcination will be left two-thirds of its weight of a simple alkaline salt; three-fourths of the other third being mere water: so great a part of this volatile oil employed in the process, flies off again, before the soap receives its just consistence.

The action between fixt alkaline salts and oil produces likewise another phænomenon. It has been formerly observed, that, when fresh urine is put to distillation, a great quantity of phlegm arises first from it: and the volatile spirit and salt are not to be raised without a strong heat, as in the distillation of hartshorn; because a great force of fire is required to disengage the volatile salt from the oil, to which it adheres; but if a large quantity of strong alkaline salt be
added

added to the urine, by the stronger attraction, there is, between this salt and the oil, than there is between the volatile salt and the oil, the volatile salt is disengaged, and permitted to assume its volatile nature, and rise from the urine with a gentle heat.

Though fixt alkaline salt will not unite with spirit of wine, but imbibe from the spirit its watry part, as has before been said ; yet if the spirit be first very carefully freed from its phlegm, it may be made to take a reddish tincture from this salt. For this purpose the salt must be melted in the fire, till it has acquired a reddish hue, and be added to the spirit, while yet warm, that it contract not any humidity from the air.

This process is attended with difficulty, the colour of the salt being probably owing to accident, as has been above explained ; and seems to arise from a small portion of oily parts, with which the salt is by chance impregnated. The practical chemists therefore usually mix a little antimony with the fixt salt, whereby they are sure of giving a tincture to the spirit ; but the college of physicians have not thought the preparation worthy a place in their present dispensatory.

Another kind of compositions is made by spirit of wine, and oleose substances. Pure spirit of wine poured upon any essential oil, dissolves it; and if it be distilled off from it, brings the purest part over with itself. Also, when any plants abounding in essential oil are distilled with a quantity of spirit of wine, the spirit brings over with it, a strong flavour of the plant. Proof spirit is usually employed in this operation, and the manner of distilling is altogether the same, as that made use of in distilling the simple water and essential oil.

The usual direction in pharmacopœias for distilling these spirituous waters, as they are called, is to take a fine proof spirit in the proportion to the ingredients, which the prescription appoints, and to draw off the quantity put into the still; but to prevent the spirit from contracting an empyreumatic tincture from the burning of the ingredients, when they should become dry; before the fire is kindled under the still a quantity of water is added, which being left at the end of the distillation will be sufficient to keep the ingredients from drying.

This method of drawing off a quantity equal to that of the proof spirit used, is the most commodious

modious for the apothecary, whose medicines must be all of the same goodness. But the distiller, who can make a diversity of price to different customers; when he has drawn off about two thirds of the spirit put on, carefully examines the spirit afterward as it runs from the still, and as soon as he perceives what runs begins to acquire a blueish, or perhaps a whitish tint, he removes, what is already come off, and collects, what runs farther, by itself. This has not so delicate a flavour as the first, and is what they call the faints. The first spirit thus reserved by itself is stronger than proof, and is reduced to the proof standard by the addition of pure water.

Their faints, when they have collected a sufficient quantity of them, are re-distilled by themselves.

Spirit of wine is also often used to draw tinctures from vegetables. It is particularly applied to extract the resinous parts from plants. Camphire it dissolves entire, very expeditiously.

The resin of jalap is extracted by spirit of wine. This is commonly performed by pouring rectified spirit on jalap root.

But this resin may be otherwise obtained. Pour upon jalap root powdered rectified spirit of

wine, and with a due heat draw a tincture, and boil the residue several times in water; after straining, draw off the spirit from the tincture till it begins to thicken; inspissate also the strained decoctions; then mix the two extracts, and with a gentle fire reduce them to the consistence of a pill.

This preparation has been so much preferred by the college of physicians for medicinal uses, that they have not given the fore-described resin a place in their present pharmacopœia.

Spirit of wine is also useful in preparing the extracts by water only of such vegetable substances, as abound in resinous parts; for though many of these parts will boil out along with the rest; yet these, by not uniting freely with the other parts, will cause the extract to crumble, and not unite into a uniform tenacious consistence as it ought to do. But a little spirit of wine then added brings the extract immediately into its due form.

By the power in spirit of wine dissolving oils, it is useful in rectifying volatile salt; for if a quantity of it be poured on the salt, and the salt be sublimed, the oil will unite with the spirit, and the salt ascend very pure.

It

It is the general doctrine, that some resinous bodies are so refractory, that they will not dissolve in spirit of wine, unless first digested with a lixivial salt. Myrrh is a subject usually proposed, as an instance of this. But myrrh will dissolve, as it were, entirely in boiling water, and a small part only will fall out of it, as it cools. This part unites with spirit of wine. If the water be evaporated, a gum is left, from which spirit of wine will take no tincture. Spirit of wine will take a tincture from myrrh without any separation of its parts, being previously made by water; and, as far as I could discover by experiment, will receive as much from myrrh, simply used, as when prepared with a lixivial salt.

Hoffman teaches, that if camphire be ground with salt of tartar, spirit of wine distilled from it will partake strongly of the flavour and taste of the camphire, without suffering any separation upon mixing with water, as happens in the simple solution of camphire in that spirit. This I have also found to be a mistake; and likewise, that there is no sensible difference in spirit of wine distilled from camphire with or without the salt.

If the highest rectified spirit of wine be poured on an equal quantity of a volatile alkaline

spirit perfectly free from any oil, and shook together, they will at once coagulate, especially if the weather be cold. This is called *offa alba* and *offa Helmontii*. But this experiment must be omitted, till we come to consider *sal ammoniac*, whence we shall produce a volatile alkaline spirit more perfectly free from oiliness, than what we can prepare at present.

A
COURSE of CHEMISTRY.

P A R T III.

Of F O S S I L S.

L E C T U R E XII.

AFTER animal and vegetable substances, the next to be treated of are those, which are dug out of the ground. These in general are called fossils. Such of them, as will melt in the fire, are distinguished by the name of minerals, that of fossils being most used to denote the rest. We shall begin with the salts.

The fossil or mineral salts are nitre or salt-petre, alum, borax, and vitriol; to which sea-salt

salt may be added, a salt of the same kind being also dug out of the ground, though usually distinguished from that extracted from sea-water by the name of fossil salt. If any of these are dissolved in water, and then the water is evaporated to a certain degree, and upon this the water be set in a cool place, the salt will precipitate from the water, and gather together in crystal-like bodies of a regular shape, but which is different in each salt.

This operation is called the crystallization of the salts, and has been already considered.

The crystallizing of salts is the securest method of purifying them from all heterogeneities. By filtering the water, wherein they are dissolved, all earthy foulness is separated, and if different salts are dissolved together in the same quantity of water, they separate from each other in shooting.

Thus much in general of these salts. To proceed to particulars, alum, and most of the vitriols, if heated, emit a large portion of water: after this distilled with a strong fire they yield an acid spirit, which is the same in either material. Sea-salt, and nitre are less humid than the others; but distilled yield also acid spirits differing from that, which is obtainable from the other salts, and also from each other. But in

order to raise the spirits from these two salts some kind of clay, bole, or other equivalent material, must be mixt with them: nitre requires three times its own weight, at least, of such a clay, and sea-salt much more; alum and vitriol require no such addition.

If either of the other salts were put to distillation alone, they would melt, and might at length be rendered so subtle, as to run through the vessel, which contained them; but would never part with their spirit. Why these clays or boles procure the expulsion of these spirits, shall be explained presently.

If borax be put to distil by itself, it swells greatly, as alum will do; but during that time emits nothing. At length that swelling ceases, and the salt after discharging a watry part melts down into a kind of glass; but is still dissolvable in water. If borax be distilled with a bolar earth, it sends out a larger quantity of water impregnated very faintly with an alkaline quality. But this quality seems only to arise from the alkaline lixivium used in refining it.

Alum has never in practice been distilled for its spirit, because vitriol, which affords the same, is a cheaper material. Vitriol is prepared for distillation by first evaporating its watry part in an earthen pan over an open fire. This salt

contains so large a share of water, that with a small degree of heat the water contained in it will liquify the vitriol, causing it at first to flow like water : but when the humidity is evaporated, the salt becomes dry. This operation is called the calcination of vitriol. When the vitriol is thus dry, it becomes of a greyish white, and in the parts nearest the fire, red. The farther this calcination is pushed, the fitter it is rendered for distilling its spirit ; because it should not clod together in the distilling vessel, and there is no danger, that the moderate heat used in calcination should deprive it of any part of its acid spirit.

But how far soever the calcination is continued, the spirit afterwards drawn from it will contain a watry part, which must be separated by a gentle distillation. What is thus drawn off will be acid, as well as that, which remains ; and the rule, by which the distillation is regulated, is to continue it, till both the liquors appear clearly transparent, whereas the spirit after the first distillation, has a blackish hue. The spirit left in the retort is now said to be rectified, and to distinguish it from that which is drawn off, is usually, though very improperly, called oil of vitriol, it is the heaviest of any fluid, except quick-

quickfilver, being not much less than twice the weight of water.

Alum calcined in the same manner, as vitriol, exhales near as great a quantity of water; but then is reduced to a white friable powder, which by distillation affords the same spirit, as calcined vitriol, and also requires the like rectification.

If this water, which evaporates from alum, be collected by distillation, towards the latter end it acquires a sulphureous smell; and the like happens in vitriol also.

The friable substance, into which alum calcines has a caustic quality from the acid spirit still remained in it, and now undiluted with water.

But this powder will dissolve in water, and by crystallization return to alum again. From calcined vitriol may also be extracted with water a salt, which is not disposed to shoot; but must be obtained by first filtering the water from the vitriol, and then evaporating to dryness.

To expel the acid from vitriol or alum it is necessary to place the vessel containing them over the fire in an inclosed furnace, that the flame may encompass it, beating on the top, as well as on the bottom and sides: the sluggishness of this vapour requires also, that the vessel be so placed,

placed, as to give it an exit laterally. The furnace appropriated to this distillation is called the reverberatory furnace.

The spirits of sea-salt, and of nitre rise more freely, and therefore neither require so lateral an exit, nor altogether so strong a fire.

From these distillations it appears, that these salts are composed of an acid spirit, and a terrestrial part. These earths differ no less than the spirits. However these salts are not found in their respective forms, because the acid spirit of each is more disposed to join with those earths, than with any other. On the contrary, the acid of vitriol will fasten upon the earth, either of sea-salt or of nitre, if poured upon either of those salts, and dissolve the union between their earths, and the spirits, to which they were originally combined.

This affords a method of obtaining the acid spirits from sea-salt, and nitre with much less heat, than by the process before described with clay or bole: for when the acid of vitriol has been poured on either of these salts, a moderate heat will raise their acid spirits from them. These spirits fly off so readily upon the affusion of the spirit of vitriol, that the operation ought indispensably to be performed under a chimney, that the rising fumes may be carried
away

away from the operator ; those from nitre especially might otherwise be attended with very fatal effects, scarce any fume being more destructive to the respiratory organs, and the life of animals, than that from nitre. If in the operation with sea-salt a portion of water is not added, the fume is so volatile, as scarce to be confined in the distillation.

In this method of preparing these spirits, the oil of vitriol joining itself with the earthy part of the salt, forms a new salt, which is found in the bottom of the retort. That, which is left in distilling spirit of salt, after it has been dissolved in water and crystallized, is used often as a gentle purge under the name of Glauber's sal mirabile. The cake left after the distillation of nitre being likewise dissolved and crystallized resembles tartarum vitriolatum, described hereafter and is usually sold under that name.

The same effect as the acid of vitriol has on sea-salt and nitre, the spirit of nitre also will have on sea-salt of dissolving the union between its earth and acid spirit. For some purposes in metallurgy a compound spirit made by mixing the acid spirits of nitre and of sea-salt together, is required. This spirit has obtained the name of aqua regia, given it from its power of dissolving gold, by those, who have been pleased to style

style gold the king of metals. But to obtain this compound, it is not necessary to prepare the two spirits of nitre and of salt separately; for if sea-salt be put in substance into spirit of nitre, the spirit distilled off will bring along with it the spirit of the sea-salt, and leave a portion of itself with the earthy part of that salt.

The power in the acid of vitriol here described makes vitriol itself a very commodious instrument for separating the acid spirit from nitre or sea-salt; for the salts being mixt with it and distilled, more acid spirit may be obtained from the same quantity of salt, than by mixing them with boles or clays.

The spirit of nitre thus distilled is usually called aqua fortis. A certain quantity of vitriol is necessary to expel from the nitre all its spirit. The refiners take equal weights for their strongest aqua fortis, but use Dantzic vitriol; the spirit could not be all disengaged from the nitre without a greater quantity of ours; but then by the redundancy of the watry part in so large a share of vitriol, the spirit would be weakened. But this may be remedied by calcining a part of the vitriol; though if all the vitriol should be calcined, the spirit of the nitre, for want of a due quantity of water to receive it, would fly off in an aerial vapour and be lost.

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The earths we before proposed for distilling these spirits operate in great measure upon the same principles: for those are fittest for the purpose that partake of the vitriolic acid.

The refiners distinguish their strongest aqua fortis from a weaker sort made by them, by the name of double aqua fortis, the weaker being called single aqua fortis. This they prepare by adding to the nitre a greater quantity of vitriol in the proportion of seven to five, without any other effect from this increase than diluting the spirit with a greater quantity of water.

The single aqua fortis, converted into aqua regia by the addition of salt, is used by dyers in the dying of scarlet. What farther preparation the spirit undergoes, before they apply it to that purpose, and why they so prepare it, shall be shewn hereafter. At present I shall only take notice, that the tincture of cochineal in water is of a dark colour, but by any acid a precipitation is made, and the colour becomes a scarlet: but the forementioned spirit makes it of the brightest colour.

(Here the experiment.)

The spirit of salt, and of nitre prepared with oil of vitriol, as above described, smoke incessantly, when exposed to the air. It is remarkable, that these fumes are heavier than the air,

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though they rise so freely ; for they soon tend downward. They are raised from the spirit, not by their natural volatility, but by the air's imbibing them : so that the air is properly a menstruum to these spirits, and, as it were, dissolves them, and disperses them about itself. The action is between the watry part of the air, and the acid of these spirits. Oil of vitriol is too ponderous to fume ; therefore on the contrary, that spirit imbibes the humidity of the air so much, that if it stand any time in an open vessel, it increases considerably in quantity.

As the acid of these spirits unites itself with the watry vapours of the air ; so on the other hand, the air sustains the vapours raised in it by its acid acting on them. The suspension of vapours in the air not having been considered in this light, philosophers have been at a great loss to account, how the heat of the sun should so rarify the water, as to make some particles of it lighter than air, which they have always supposed necessary to be done, that the vapours might be suspended. But it is evident, that the air will even imbibe water without much heat : a wet cloth in the coldest night short of freezing will gradually dry. The warmth of the air contributes indeed much to the elevation and suspension of vapours, both because water is a volatile

atile substance, and raised with a small heat, and as heat increases the action of all menstruums. But, though heat alone will raise vapours from water, without the action of the air upon them they soon fall again.

When the vapours have diffused themselves high in the air, by the cold of those upper regions they are condensed into visible clouds. In winter the coldness of the lower air will condense them, and cause fogs; a fog being only a cloud flying contiguous to the ground. But in the warmest weather the air high above us has but little heat. The heat, we have here upon the earth from the sun, is two fold. One is the degree of heat resulting from our particular distance from that globe of heat, as well as of light. The heat we receive from this cause is that, which we compare with the like heat other planets receive from the sun; and is the same to us by night as by day. The other cause of heat from the sun is the action of its rays upon the bodies, they shine on: and different bodies receive very different degrees of heat from thence. Metals, and other the most dense bodies, conceive, by lying in the sun, the greatest heat: but bodies of less density are less heated by the same degree of sun-shine. The air, being a

very rare body, will receive but small heat from the sun's rays passing through it. The heat of the lower air is reflected from the earth. The great heat of the lower air above the upper is that, which causes hail. The upper air by its cold has frozen the vapour into snow, which in falling is so far melted, as to unite together into a body of ice, which snow always does, when it begins to melt. Hence it is, that hail falls in warmer weather, than snow does, and hailstones are frequently found with snow in the middle.

I shall now say something of the method, how these salts are obtained originally.

Sea-salt is got by evaporating the sea-water, which in warm countries is done by the heat of the sun. Thus bay-salt is made. In hot summers bay-salt is sometimes made in England. But in this country we supply the want of sun by actual fires. In the salt-works near Newcastle, where coals are of little cost, they boil away the water directly taken out of the sea. In other places they spread the water into shallow square receptacles dug in the ground, which they call pans, where the water in part evaporates first ; and then they finish the work by fire.

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The same kind of salt is also dug out of the earth, and is cleansed from the impurities mixt with it, by dissolving it in water.

There are also salt springs, whose water boiled away leaves just the same kind of salt. We have several of these in England. In these the water is much more strongly impregnated with salt than the water of the sea. In boiling away these waters to collect the salt, they free them from impurities by mixing with them blood or the whites of eggs. Blood, in particular the ferrous part, and the whites of eggs coagulate by heat: stirred therefore with the boiling liquor, while they coagulate, they intangle the impurities, and rise with them up to the top. Where salt is made from sea-water, and the water has stood in pans a great length of time to evaporate; its foulness subsides, so that it is not necessary to clarify it.

I said above, that this salt crystallizes, while the water is hot. The grains are rendered larger by this artifice. Some unctuous or resinous substance (suppose rosin, or what is at present particularly in esteem, gum-sanders) mixt with butter is in a small quantity dipt into the liquor, when it is boiled so far away, that the salt would soon be left a dry cake, and then the fire is checkt, that the liquor may just cease

from boiling. The oily substance spreads itself over the surface of the liquor, and contributes to separate an acrid saline substance contained in the liquor, which would obstruct the crystallization of the salt. It has been lately discovered, that a very minute quantity of alum will perform this still more effectually. The salt granulates at the top of the liquor, and falls to the bottom. This is taken out with ladles, and laid in troughs perforated, that it may drain. The liquor, that drains from the salt, contains another salt, that will also crystallize, but not while the liquor is hot. But this liquor being left open to the air, this salt separates out of it, and concretes into large irregular lumps, which being dissolved again divides into the fore-mentioned acrid, saline substance, which does not shoot into crystals, but only subsides, and another salt, which crystallizes over it, those two being separated by a thin crust of common salt. This crystallized salt resembles that contained in the purging-springs. And this is the salt, which is every where sold under the name of Epsom salt.

All the nitre, which has long been used with us, comes from India, where it is made from the earth of a soil near the city of Patna abounding with it, much after the same manner, in
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which it was formerly made here, and is still in several countries in Europe, from earth exposed long to the air, but kept covered from the sun and rain, boiling this earth in water to extract the salt, and filtering the water through ashes to free it from an oiliness, which comes along with the salt from the earth.

Alum is dug out of particular mines, and is contained in a stone, which is first to be calcined, then steeped in water, by which the alum is extracted. A water also sometimes issues from the sides of the mine, which yields pure alum, by evaporating with the sun's heat only. But to the alum extracted by water from the calcined stones, so much of the stony part still adheres, that it is necessary to separate it, that the alum may crystallize. This is performed with kelp and stale urine. How these materials accomplish this, will appear at our next meeting. Kelp is the ashes of the kali, and often hangs about oyster-barrells.

Vitriol is of three kinds, green, blue and white. They agree in the same acid spirit. The green is most used, and this kind is usually called copperas. These vitriols differ chiefly in a small portion of metal, which is in them. The blue vitriol has copper in it, the white, the

mineral called zink, and the green, iron, of which indeed they all in some measure partake.

The green vitriol is made here in England, and is freer from any other metal, but iron, than any of the foreign. It is drawn from stones found on the sea-shore in places, where the soft earth is washed by the sea. In such places, as the earth is continually worn away by the surges, these stones are uncovered. These stones must lie some years exposed to the sun and rain; till at length a liquor runs from them, which is boiled up with iron. The iron is corroded and consumed with the liquor. The liquor being boiled away to a proper degree, and set in coolers, the copperas crystallizes to the bottom and sides of the cooler. The iron furnishes the copperas with some of its metallic part, but not with all of it: for copperas may be made from this liquor without iron, though not so plentifully; and sometimes copperas is found to be shot from the liquor before boiling, as it lyes in the sun.

The liquor is boiled in leaden vessels; because it will corrode iron and copper.

These stones contain sulphur or brimstone in them, also iron. Hereafter we shall see, that common brimstone contains the same acid spirit,

as

as is produced from vitriol. While these stones lye in the open air, they undergo a kind of fermentation, whereby the acid spirit is set loose from the other parts of the sulphur. This spirit thus disengaged corrodes the iron, and produces vitriol. That this spirit will convert iron into a salt resembling vitriol, we shall see hereafter. As the acid spirit in these stones, is more than what suffices for the iron in them, iron added in the boiling of the liquor increases the quantity of the vitriol.

In Saxony near some of the copper-mines they find an earth and stone, which steeped in boiling water, as soon as dug up, impregnates the water with copperas, which is obtained only by boiling away the water, till the copperas will shoot from it.

At the same place white vitriol is made by steeping in cold water a particular kind of lead ore, which contains zink or spelter, and boiling down the water, till the vitriol will shoot from it. And then the vitriol is farther whitened, and some part of its humidity evaporated by another operation upon it, which they call calcining it. This is performed, by putting it into a copper vessel, and with a proper heat melting the vitriol and boiling it for some time, afterwards

wards it is removed into wooden troughs, where it is stirred about, till cold.

If these stones abound in copper, blue vitriol will be produced. Of these we have none in England.

In Germany blue vitriol is prepared by mixing together two minerals, one of which furnishes the vitriolic spirit, the other being a poor kind of copper ore. They are beaten to powder, and washed from the light earth mixed with them, then calcined together for some time, and afterwards boiled in water.

In some countries copperas stones abound much more with sulphur than ours. Common brimstone is frequently melted out of such stones.

Borax is obtained by crystallization from a mineral called tincal; after the tincal has been duely purged from an unctuous part, wherewith it is charged. This salt also shoots from the liquor while hot, and best, if the vessel be covered.

LECTURE XIII.

IN the mineral salts, I have had under examination, the acid principle appears in fuller force, than it does in vegetable subjects.

Wherein the acid spirits differ from each other is difficult to say. Possibly they all agree in one common acid principle, and that their difference arises from some adventitious matter, to which the acid is joined. Whoever could prove this, or could certainly shew the contrary, would make an important discovery in chemistry. In the mean time we may observe, that there are but four acid spirits known in nature; the vegetable acid, (which appears in its greatest purity in vinegar,) the spirits of nitre, of sea-salt and of vitriol.

By the distillations described in the preceding lecture, it appears of all these salts, except borax, that they are compounded of an acid spirit, which is expelled from them, and of an alkaline earthy part, wherewith the acid was united. By this union the acid taste is lost, and another produced; insomuch that both the acid and alkaline qualities disappear, and some third quality,

lity, differing from either, results from their union.

The experiment may be made thus. The acid spirit is to be poured by degrees on a solution of some alkaline salt in water, or on an alkaline earth in powder. At the first affusion a strong effervescence arises; and as soon as that has ceased, more of the acid is to be poured on, and the operation repeated from time to time, till no farther effervescence is observed. Care is to be used, that the solution be poured on no longer, than till the liquors just balance each other. Then, if this liquor be duly evaporated, a salt will shoot from it.

When the experiment is made with spirit of nitre, and a fixt alkaline salt, the salt obtained resembles nitre so much, as scarce to be distinguished from it: it seems to be the very same salt.

The salt thus produced from the spirit of sea-salt shoots into the same form, as sea-salt itself; but has not the same taste. Here the salt produced in part resembles the original salt, whence the spirit was drawn, but not so perfectly as in the former case. The earthy part therefore of nitre seems to be the same, as that of fixt alkaline salt, which is a vegetable earth. The earthy part of sea-salt is something different.

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When the acid spirit of alum, and that called oil of vitriol, is poured in like manner on a fixt alkaline salt, the salt produced differs yet more from the original salt, whence the acid was extracted. This is most commonly made with oil of vitriol and salt of tartar, and is called tartarum vitriolatum.

(Here mix ol. vitriol. with sal tartar. for tart. vitriolat.)

If these experiments are made with a volatile alkali instead of a fixt, a saline body in some degree volatile is produced.

If spirit of salt be poured gradually upon any animal volatile spirit, as upon spirit of hartshorn, of urine or the like, it produces a salt like that called sal ammoniac, so named from the temple of Jupiter Ammon, or at least from the sands of the neighbouring desert, being conceived to have been originally produced from the urine of the camels passing through that desert by its mixing with a saline soil. It is at present made in Egypt, but by what process has not yet been perfectly known to us.

If this salt be put in a low glass vessel with a wide mouth or in a retort, and set in sand, by a strong degree of fire gradually raised upon it, the salt will wholly sublime, except a few earthy dregs left at the bottom.

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Though this is an operation of little value, for the salt is better purified by solution in water. Yet if a portion of a fixt alkaline salt be added to it, it will rise very white, otherwise not.

But by mixing the alkaline salt in a due proportion, the sal ammoniac may be decomposed, and the principles of which it consists made very manifest; for the alkaline salt will draw to itself and retain an acid similar to that of sea salt, and disengage a volatile alkaline salt perfectly resembling that obtained from animal substances, which by this means will ascend alone. If water be added to the mixture it comes over in the form of a spirit, and is called the spirit of sal ammoniac.

What remains at the bottom is no other than the spirit of sea-salt joined with the fixt salt made use of.

The volatile salt from sal ammoniac is freer from oil than any, we have hitherto produced from other substances. It may be impregnated with the flavour of vegetable oils in this manner. Put any aromatics of an agreeable odour into spirit of wine together with some sal ammoniac, and a quantity of fixt alkaline salt: then distil the whole in a gentle heat. The fixt alkali separates from the sal ammoniac its volatile salt, while the spirit of wine extracts the odoriferous
oils

oils from the other ingredients. Thus the spirit comes over impregnated with those oils and volatile salt united. This preparation is called *spiritus salis volatilis oleosi*. And may be more compendiously made by distilling *spiritus salis ammoniaci dulcis* from aromatic essential oils.

The acid spirits of all the salts, except nitre, have a stronger tendency to unite with the alkaline salts, than with their own, or any other earth. The vegetable acid in tartar ferments with an alkaline salt, and deposits its own earth. A solution of an alkaline salt poured on a solution of sea-salt, alum, or vitriol makes a precipitation from them.

In nitre, if pure, the experiment does not succeed, whose earthy part is the same with that of the fixt alkaline salt, as appears both by the experiment above described of regenerating nitre from its spirit, and a fixt alkaline salt, and also from the production of a fixt alkaline salt from nitre by a process presently to be described of burning out its acid spirit.

Though either of the alkaline salts produce the effects now mentioned, yet there is a difference in their acting on these spirits; for the spirits have a stronger tendency to unite with the fixt alkali, than with the volatile.

Upon

Upon this principle it is, that the volatile salt is recovered again out of the sal ammoniac by the help of a fixt alkaline salt.

The power in alkalis now mentioned to make a precipitation from alum is the reason, why they are used in the manufacturing that salt. Without their help the alum would contain too much of this stony part, which they precipitate.

This property of alum has made it useful for preparing several pigments.

Mr. Boyle has in good measure described the method. And Antonio Neri, in his art of making glafs, is still more particular in his account of them. He calls these pigments lacs.

A lixivium or lie of moderate strength being made with a fixt salt (if you please its force may be increased with a little lime.) With this lixivium is to be extracted in a gentle heat the tincture of any flowers, woods, or the like, whose colours will not be spoiled by the fixt salt. This tincture being strained off, is to be set over a fire and boiled, and as much alum thrown into it, as it will dissolve. Straightway the stony part of the alum, precipitated by the fixt salt, will separate from the liquor, tinged with the colour of the tincture.

The Prussian blue, a colour in great reputation, is made after the like manner, though the
pro-

process is a little more complex. It is this. They first mix a quantity of blood dried with an equal weight of fixt salt, and calcine them together in a covered crucible. The heat at first should be gentle, afterwards raised. The matter during the calcination flames and glows. The higher the calcination is carried, the deeper will the colour be. When the calcination is finished, they break the matter in a mortar, and boil it some time in water : one pint of water is enough for each ounce of the blood used. Then for each ounce of blood one quarter of an ounce of English vitriol calcined, till it is white, and half an ounce of alum, or more, are to be dissolved together in the same quantity of boiling water, the two liquors are to be filtered, then mixt together boiling hot. Immediately ensues a great ebullition and green colour. The mixture is poured from one vessel to another as long as the ebullition continues. After this, being strained through a cloth, a pigment is left behind.

When this is well washed to free it from the loose salts, it becomes of a beautiful blue colour ; or if it prove less perfect, a little spirit of salt readily corrects the defect.

Upon the same principles alum is useful in dying. All the dyers of woollen, except those
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who dye in scarlet, boil their cloth with alum, before they put them into the tinged liquor, that is to give it its colour; and with all their colours, except cochineal, they mix either some fixt salt, as pearl-ashes or pot-ashes, or else putrid urine. These alkalis extract the acid of the alum adhering to the cloth, leaving the stony part, which I have already shewn, that those substances extract from alum; and this stony part of the alum, is a body proper to receive the dye. In order to fix this stony part of the alum firmly to the cloth, they find it useful to add tartar to the alum. They boil their cloth before dying in water, wherein both alum and tartar are together dissolved after the rate of about thirty pounds of tartar to eighty of alum.

I mentioned just now, that nitre might be converted into an alkaline salt, by burning out its acid spirit; this may be performed after the following manner.

If nitre be melted in a crucible and pieces of charcoal thrown upon it, it will flash and blaze out vehemently. This operation may be repeated so long, till no farther flashing will follow the throwing in of the coals. Then what remains of the nitre, is a fixt salt, and may be separated from the ashes of the coal by steeping them in water, and proceeding according to the

method before taught for extracting the fixt salt from vegetable ashes

This process is called the detonation of nitre.

The like denotation happens, though not so vehement, when nitre and tartar are mixt together in equal portions, and thrown gradually into a red-hot crucible. And by this means a strong alkaline salt is instantly produced.

Nitre exposed alone to the greatest heat will never take fire, but melt like other salts. But if added to any inflammable substances, it very highly increases their inflammability: for this fulmination succeeds, whatever inflammable substance is thrown upon the nitre.

The spirit of nitre, drawn as before described with oil of vitriol, will burst out into a flame, when poured on half its quantity of any oil very free from acidity; such as the ponderous oils of the eastern spices, and animal oils.

It also appears farther, that the concurrence of an inflammable substance is necessary toward the production of fixt alkaline salt; for when the acid of the nitre is expelled by simple distillation, the earthy part only of the nitre is left; but here a part of the acid seems to be retained, and so united with a portion of the sulphur of the coals, that it cannot be separated from the salt in any other form, than that of an aerial va-

pour. And this effect is produced by distilling any fixt alkaline salt mixt with thrice its weight of bone-ashes or the like simple earth. We shall hereafter see other methods of producing air from a union of acid and sulphur.

The experiment succeeds best, when the distillation is finished with a moderate fire.

This is a very instructive experiment. In the first place it shews, to what part of the nitre we must ascribe its power of increasing the inflammability of bodies. In the next place this experiment shews us, to what principles the phosphori owe their sudden inflammability. The phosphorus from urine dissolves in the air into an acid liquor; therefore is compounded of an acid and inflammable substance united together. The phosphorus with alum to be described at our next meeting, has the acid spirit of the alum joined to an inflammable substance.

We may also learn from hence, on what principles the air procures the inflammability of bodies. That the air contains in it an acid, its effect on metals makes manifest, as we shall see hereafter; nay that the acid of the air nearer resembles that of nitre, than any other known to us. And by this experiment it appears probable, that inflammable bodies are set on fire, by the acid of the air acting on the inflammable sub-

substance in the body. As a certain degree of heat is required to excite this action, so, where the body already contains a large portion of an acid spirit, that spirit, when the body is heated, assists the air in its operation; so that a less heat is necessary to fire those bodies than others. Hence it is that not only the phosphori take fire sooner than other bodies; but common brimstone (which we shall find hereafter to be compounded of an inflammable unctuous substance and an acid spirit) catches fire with less heat than simple oil.

The reason, why our experiment scarce succeeds with oils, that have any acidity in them, is this. The oils are cold, wherewith the experiment is made, therefore the acidity within them is not put in action to contribute any thing toward their heat. And the action between the acid spirit poured on, and the oil is much stronger, where the oil is wholly destitute of acidity, than in oils, that have already some portion of acid; just as we see in the saline liquors, which ferment, the fermentation is stronger upon the first affusion than afterwards. Common brimstone being at full impregnated with acid, will not be acted on at all either by the acid of nitre or any other.

But by the affusion of every acid spirit upon any oil, a degree of heat will be produced, though it be not great enough to set the oil on fire. The forementioned spirit of nitre will set even oil of turpentine on fire, if its action be assisted by making the oil first a little warm.

The acid spirits will also excite a great heat and fermentation with spirit of wine. Mixing thus these acid spirits with the vinous one is called dulcifying them. The spirits of salt and of nitre are commonly thus dulcified, that they may be taken safely into the stomach, as medicines.

After they are mixt, it is usual to distil them; by this means the acid spirits are certain to be impregnated with their due quantity of the vinous spirit.

When oil of vitriol is mixt with spirit of wine, the mixture upon distillation, parts into different liquors, though not into those whereof it is compounded. Mr. Boyle describes this process at large. The first liquor, that ascends with a very gentle heat, is a light spirit more inflammable, if possible, than spirit of wine itself, and differs from spirit of wine in its smell. Moreover, if this process is conducted with proper circumstances, the liquor produced, though by its great levity and volatility it retains the name of spirit, is in reality an oil; for it will not unite
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with water, and is the spiritus vini ætherius introduced among us under this name by a German chemist, Frobenius. This inflammable spirit is followed by others. At last a black pitchy substance, but tasteless, and not inflammable, is left behind.

This property in vinous spirits, of mixing with and dulcifying acid ones, is that, which gives them the power, we formerly mentioned, of checking fermentation in vinous liquors. Dulcified spirit of nitre will not ferment with lixivial salts.

The acid spirits in some measure coagulate all oils, they are mixt with. The spirit of nitre will not incorporate wholly with olive oil; but though the oil remains on the top of it, it will receive such an alteration from the spirit, as to become of the consistence of butter. Oil of vitriol mixt with essential oils unites with them into the solid consistence of a pill.

From this effect of acids on oleaginous substances, we may form a probable conjecture concerning the cause of that surprizing property of the serum of the blood, and of the white of eggs, peculiar to the animal juices, that of being coagulated in its whole substance by a small heat: for the strong acids have the same effect upon them without any heat, and alkaline spirits

obstruct this effect of heat, as Mr. Boyle has discovered. It is therefore reasonable to suppose the blood charged with so much of an acid principle as will produce, by the means of heat to augment the power of the acid, this effect. Probably the greater consistence of the fat of animals above that of the oils of vegetables is owing to the like coagulating principle.

Camphire is liquified by spirit of nitre. Oil of vitriol dissolves it wholly, and holds it down so perfectly, that no smell can be perceived. Water poured into it raises the camphire, and then it exhibits its usual smell.

Here we conclude our examination of salts. Mineral sulphurs are next to be considered.

LECTURE XIV.

AFTER the salts, we proceed in the next place to consider sulphurs; the right understanding of which is very necessary in the treatment of metals; metallic ores being generally a composition of the metallic part, and a sulphur united with it; and the art of refining consists very much in dissolving the sulphureous part, so that it may separate from the other.

The nature of these sulphurs will be understood, by what we are going to exhibit on brimstone, the most common of them.

There are two species, under which may be ranked the substances generally attending metallic ores. They are also found where no metal is near. These two are spars, and what in several parts of England are called mundicks. Spars are crystalline bodies, formed in angular shapes, as salts shoot. Mundicks are sulphureous substances, by the Greeks called pyrites, and by the Arabians marcasites. Their general character is to have a sulphureous smell and to strike fire with iron or steel.

These all contain a considerable quantity of sulphur, that may be obtained from them by
2 sublimation.

sublimation. Some so abound with brimstone, that it melts out with a small heat. This is one way common brimstone is made.

It is a compound body consisting of an inflammable part, an acid spirit, like that drawn from alum and vitriol, and an earth charged with an inconsiderable portion of metal. But the acid spirit is not to be separated from it, as from salts, by distillation; for thus treated it sublimes into flowers, and by this sublimation is purified. To separate the acid spirit, the ordinary method has been to set the brimstone on fire under a glass of a proper form to receive the fume: for by this means, while the inflammable part is consumed by burning, the acid spirit uniting with the moisture of the air condenses upon the glass, and trickles down by the sides of it into a large dish placed to receive it, the earthy part being left after the sulphur will burn no longer.

This glass used to be formed in the shape of a bell; but, whereas the rim of a bell turns outward, it has been found most convenient to turn the rim of this glass rather inward, and also to draw the top of the bell out into a long stem left open to give passage for the smoke, which otherwise must come out from under the bell, and be very offensive to the operator. However

However this glass, though altered a little in its form, goes still by the name of the sulphur bell, and the spirit thus made is called *spiritus sulphuris per campanam*.

Water impregnated with the fume of sulphur, has been usually called *gas sulphuris*, but in the present pharmacopœia *aqua sulphurata*, this water receives that part of the sulphur, to which its inflammability is owing, accompanied with a small share of acidity. The power of sulphur, in restraining the fermentation of vinous liquors, which have been fumigated with it, seems chiefly owing to this inflammable part; for spirit of wine, as we have observed before, is indued with the same power.

The inflammability of sulphur has given occasion to chemists, in their philosophy to call the inflammable part of all substances their sulphur. The character of fossile sulphur is to melt with heat, though in the cold it be hard and brittle, soon to take fire, and burn with a flame, and to be indissoluble in water or in any acid spirit. The substances found in the earth, which agree with this description in all but being hard in the cold, are called *bitumina*.

In most of the subjects we have hitherto examined, we have made use of the simple application of heat to decompose them. In some
few

few instances that method has proved ineffectual. The coal resulting from the distillation either of animal or vegetable substances, could not be deprived of the principle, to which it owes its blackness, and its power of burning, by mere heat. Sal Ammoniac, another compound substance, will not divide by heat alone, but the whole sublimes together. The like happens to sulphur, which, heated in a close vessel, sublimes intire, and this operation is usually practised upon sulphur to purify it. Sulphur thus sublimed is called the flowers of sulphur. For sale it is thus sublimed. The sulphur is thrown into iron pots set in a furnace and heated. The pots have a moveable cover, which is taken off to throw in the sulphur, and presently stopt down again. An iron pipe opens from each pot near the top, into a room big enough for a man to enter. Into this room the sulphur flies out of the pots upon its subliming, and settles upon the floor, and sides of the room. When the operation is finished, the flowers of the sulphur are swept together with a broom.

Several preparations are made with sulphur by dissolving it with proper menstruums. Neither water nor any acid spirit will operate upon it. But oils and the fixt alkaline salt of vegetables

bles do dissolve it. Flowers of sulphur boiled with four times as much oil in an open vessel, will unite by the evaporation of the watry part of the oil into a uniform substance of a consistence, whence it receives the name of balsamum sulphuris. This is most usually prepared either with oil olive, oil of turpentine, or oil of aniseeds.

Fixt alkaline salt melted with sulphur makes it dissolvable in water. Sulphur thus melted with a fixt alkali is called hepar sulphuris. Sulphur may also be dissolved in water by boiling it in a solution of a fixt alkaline salt; for thus the alkaline salt will dissolve the sulphur, and give a tincture to the water therewith. Upon this tincture if any acid spirit be poured, it presently becomes turbid, and a powder subsides; which after frequent washing by stirring it with a large quantity of water, and as soon as it subsides, pouring the water from it, is called lac sulphuris, and magisterium sulphuris. Melted it turns yellows, and reassumes the ordinary appearance of brimstone. This process is also performed with lime, as we shall shew at our next meeting, and is the only method, in which the preparation is, in the way of business, made.

Sulphur

Sulphur thrown upon nitre in fusion inflames violently with the nitre, and causes an explosion. If this be done only, till the nitre flows clear like water; the nitre then poured out is called *sal prunellæ*. If as much sulphur as nitre be used, the result is, what is called *sal polycrestus*, a medicine much celebrated by writers, but at present scarce in use here. It differs not essentially from *tartarum vitriolatum*, the acid of the sulphur having dispossessed the acid of the nitre from its earth, and taken place in its room. In *sal prunellæ* the alteration, the nitre undergoes, is so small, that with us it is little regarded, there being no manifest reason for preferring it to nitre purified by crystallization only.

This sudden fulmination of nitre with brimstone is the principle, upon which the action of gun-powder is founded. That powder is only a mixture of nitre, and brimstone with charcoal dust. The use of the charcoal is to set the composition suddenly on fire.

There is a great difference in authors with regard to the proportion of the ingredients, some advise to take equal parts of charcoal and brimstone; others direct twice as much of the coal. They differ also in the quantity of nitre.

The

The powder is much improved by well mixing the materials. This is of more consequence than an exact observance of the proportions. The powder made here in England, for the government, is composed of 75 pounds of nitre with 15 of charcoal and 10 of brimstone. For the use of merchants the powder has less nitre and more charcoal. The corning it is also an advantage towards its sudden taking fire. This requires a double sieve. The holes of the uppermost being as large, as the corns are intended to be, the under smaller. The powder, so moist as to form a kind of paste, being put into the upper sieve with a piece of wood, that may break it to pieces, while the sieve works. The under sieve lets the dust fall away, but retains the corns. In practice a treble sieve is generally used with holes gradually smaller. The corns stopt at the second sieve are used in great guns, and therefore called cannon-powder; the smaller corns stopt by the third sieve make the pistol-powder used in all small guns. The workmen have a contrivance to make the corns of gun-powder look shining, which they call glazing it. This is done by shaking the powder in a barrel, that has held black lead.

There is another mixture called pulvis fulminans, made by putting a fixt alkaline salt to the
nitre

nitre and brimstone instead of charcoal, which explodes perhaps with more force than gun-powder itself; but this will not suddenly fire. It must be gradually heated over coals.

The proportions for this mixture are three parts of nitre, two parts of the alkaline salt, and one of brimstone.

The sudden accension of gunpowder is owing to the power, we have before remarked to be in nitre of increasing the inflammability of combustible substances. And the vehement explosion arises from the large quantity of air, into which great part of the gun-powder is converted upon its accension. This has been found to be the case by firing gun-powder in a close vessel; for here a great quantity of air is seen to be at once produced.

The inflaming power of nitre is the cause, that gun-powder is the only combustible substance, that has yet been experimented upon, which will fire in a vacuum. Even the phosphorus of urine, which in the open air takes fire with so very little heat, and burns so fiercely, as we have seen, cannot be enkindled in a vacuum. But the nitre in gunpowder supplies in some measure the place of air.

However the presence of the air is so far necessary to the sudden accension peculiar to gun-powder,

powder; that if it be not formed into corns, or if in dust lie loose, whereby the air may be plentifully diffused through it, but being reduced to fine dust, be rammed down close; it then will not explode at once, but burn upon its surface only.

For this reason in all fireworks, where the powder is to burn gradually, it is beat into dust.

This power in nitre to promote the inflammability of other substances, makes it a necessary ingredient in all fireworks; in those, where no explosion is desired, as well as in those, wherein an explosion is made.

The principal of artificial fireworks made for diversion are rockets. Upon these the construction of most of the rest depends. And as the effects of rockets depend upon the subject now before us, it may not, perhaps, be amiss to describe briefly their structure.

A rocket is a hollow cylinder usually made of paper, of a thickness equal to about one-sixth of its diameter within, and fill'd with gunpowder or some like composition. If a rocket be made of great bigness, intended for a signal in war or such like use, its case may be made of a more solid material.

Near one end the case of the rocket is drawn in, till its diameter be reduced to one-half of

the whole internal diameter. This place is usually called the choke. The most approved length of the case from the choke is about six times its internal diameter, to be filled with gunpowder; if the rocket be small, beat into fine dust, and rammed in with as even strokes as can be, that the powder be uniformly compressed. In great rockets the charge is usually a little weakened by adding to the gun-powder a small portion of charcoal and of sulphur.

To the end of the rocket is added a cylindrical cavity not above half the length of the rocket from its choke in height, and of such a diameter, that, together with the materials put into it, it may not exceed the weight of the rest of the rocket. These materials, besides some corn-powder to burst the case, consist of some composition, that may give the appearance of stars, a shower of fire, or the like.

These fiery showers may be made of saw-dust boiled in water strongly impregnated with nitre, and while wet rolled among gunpowder in dust; or by gunpowder mixt with melted brimstone, and when cold grossly beaten.

These stars are a mixture of gunpowder, nitre, sulphur, antimony, camphire, and the like combustible materials moistened with a solution of some gum, thereby to form pellets of a convenient

venient size. These pellets are to be covered over with thread well soak'd in a strong solution of nitre and while wet roll'd in gunpowder. To charge the rocket with larger balls, any of the foresaid ingredients (whereof nitre in a sufficient quantity must always be one) may be mixt with turpentine, melted pitch or rosin, and tow steep in it. This way larger balls may be formed, which should be covered over with thread prepared as just now described.

It is necessary for giving the rocket a sufficient degree of motion, that the powder within the rocket be bored with a tapering cavity from the choke. At the choke this cavity must be as wide as the choke itself, at the farther end it need not be more than one-half of that width. The length of this bore must be but one inner diameter of the rocket short of the whole height, to which the rocket is rammed. The use of this bore is to increase the surface, that takes fire at once; that a greater body of fire may issue out of the mouth of the rocket. For from the vehemence, with which the fire issues out, the rocket receives its motion. Rockets are used in all fire-works, that have motion, except such as are thrown into the air after the manner of bombs. When the rocket is designed to mount upwards, a stick eight or nine times the length

of the rocket is tyed to it, sufficient to poize the rocket at an inch or two from its mouth.

Nitre furnishes other compositions useful in war besides gun-powder, upon the same principles.

If nitre be mixt with pitch, rosin, turpentine, sulphur and such combustible materials, and tow be steeped in it; fire-balls formed of this tow will serve to illuminate any place desired. If the tow be gradually wound into a ball, and from time to time first dipt in this mixture, and then roll'd in gun-powder, the ball will burn yet fiercer, and such a ball will not only be useful in giving light, but therewith an enemy may be annoyed, in particular any edifice may be fired with it.

Bombs and grenados, which are only iron shells filled with gun-powder, are to be light, before they are delivered; but the powder must not take fire, till they arrive at the place designed. For this reason a hollow piece of wood resembling in shape the foffset of a tap is drove into them, and the hollow of this wood is fill'd with a combustible material, that will burn slowly. This is usually made of pulverized gun-powder with an additional quantity of some of the other ingredients, to alter the proportion they

they have in the gun-powder. This matter is rammed hard into the cavity.

It is from the analysis of sulphur, that we must learn the cause of the great combustibility of the phosphori. The phosphorus from urine I have before observed to contain, besides its inflammable part, an acid spirit: That invented by the late famous Homberg is a union of the acid spirit contained in alum with an inflammable part from animals or vegetables.

This phosphorus thus compounded of alum, and some animal or vegetable substance, takes fire the most readily of any thing yet known: for being thrown out of the bottle, which contains it, into the open air, it fires immediately and burns, what it lies upon, without any assistance by rubbing, or by any warmth applied.

No mineral substance mixt with allum will make this phosphorus, nor any salt but allum.

The most ready method of preparing this phosphorus is to put the alum mixt with the other material into a crucible, and heat the mixture gradually, till it grows red hot and burns with a small blue flame; breaking the mixture from time to time during the operation, that it may not concrete into one mass: then it must be taken immediately out of the crucible, and put into a vial made hot enough

not to be broke by the heat of the matter put into it,

Arsenic is usually considered by the chemists along with sulphurs. But improperly. I shall consider it among the imperfect metals. Orpiment, frequently confounded by writers with a factitious substance called yellow arsenic, is a mineral properly to be called sulphureous.

But to conclude let me farther say something of that ambiguous substance amber, which has at length been discovered to be a fossil.

It was indeed most usually found floating on the sea. But it has lately been dug out of the earth in Prussia: where in digging they found first a stratum, which had the appearance of old wood, and was combustible; immediately under this was a layer of copperas stones. These lay upon a bed of sand, out of which they got pieces of amber in great plenty.

In distillation it yields an acid spirit, a finer and a grosser oil; also a volatile salt in a solid form. This salt is not an alkali; but contains an acid spirit so loosely adhering to its earth, that it will ferment with alkalis even without heat, which scarce any other salt will do. The acid of this salt is the same, with that of the spirit, which rises with it in the distillation.

At

At the end of the distillation of amber there is left at the bottom of the retort a black pitchy substance.

The salt of amber comes from the subject, as other volatile salts do, foul with oil. This salt is not so volatile, as to rise with the heat of boiling water. And the usual way of purging it from its oil, is to boil it in the spirit, or in simple water, and set it by to shoot.

LECTURE XV.

Of STONES.

HITHERTO the greatest part of our operations, upon the subjects, we have handled, has been to analyze them, and reduce them into the principles, whereof they are compounded. But the present subjects are so simple in their structure, that our chief purpose will be to shew the effects, they produce, when compounded with other substances.

We shall here consider stones. Some of these are transparent, others not. Of the transparent, those, which exhibit the most beautiful colours and lustre, are called gems. Gems are rivalled in transparency by glass, but are preferable to it in degree of hardness; by which means they take a much finer polish. They are often imitated by coloured glass, but are easily distinguished by the weight. Precious stones being much heavier than glass. They have even the greatest specific gravity of any stones. The heaviest of these is the diamond. But this stone cannot possibly be counterfeited to any perfection; be-

because its beauty is not owing to any colour; but only to its eminent lustre, which arises from its great refractive power. By this quality it reflects much more light than any other transparent body whatever; those bodies in general reflecting most light, which have the greatest refractive power. By this quality also it exhibits, when its surface is formed into a variety of different planes, a greater diversity of colours, and those much more vivid, than can be exhibited in like manner by any other transparent substance. But the consideration of gems has no direct relation to our present undertaking. With regard to stones of the transparent kind we shall only here observe, that sand, which is a heap of very minute stones, and flints calcined in the fire, till they can be powdered, will melt with any vegetable fixt salt into glass. But glass does not melt as salts and metals do. They flow thin like water; glass melts into a tenacious consistence. Hence it is, that glass upon its first melting appears full of small blebs or bubbles. These arise from the air, that is copiously lodged among the materials, they being powders. And as the glass melts into a tenacious consistence, the air in these bubbles extricates itself but slowly. Length of fire expels it, and renders the glass uniformly transparent.

In glass-houses the fire is kept up night and day without intermission, as long as the building will endure, and as their pots work out, they fill them up again with fresh materials. In the bottle glass houses their pots are worked out in one day, and fresh materials melted in them in the night.

This tenacious consistence of melted glass, is the reason, that it is wrought otherwise than melted metals are. Melted metals are always cast into a mold. But glass is taken up by putting into it the end of an iron pipe red-hot. A portion of glass will stick to the pipe; and the pipe being hollow the glass is blown up by the breath of the workman, and shaped with iron tools, and by rolling it on a marble. If the glass cools and grows hard, before it has received the desired shape, it is put from time to time, while on the pipe, into the furnace, and held there, till it grows soft enough to be wrought on.

Iron is the only metal to which glass adheres; the reason of which shall be assigned hereafter. The fire of the furnace is not kept altogether up to so intense a heat, while the glass is wrought, as while it is melting.

Common red sand and the ashes of wood or straw melted together, make the green glass used
for

for bottles. This glass is the least tractable of any, and does not melt soft enough to be moulded so freely, as finer glass, into any shape. Though the materials for all the other kinds of glass, except that called flint glass, differ from this bottle-glass only in the whiteness of the sand, and the purity of the ashes. In the bottle-glass red sand, and the earthy part of the ashes, as well as the fixt salt are mixt together; for glass more transparent ashes in some degree purified are used. In the finest Venetian glass, which was once in great esteem before the invention of flint glass, they used fixt salt entirely purified from the earthy part of the ashes.

Flint-glass has lead in its composition, and we shall more fully describe it, when we come to speak of the glass of lead. It is called flint-glass, because it was first made with calcined flints; but now they use only fine white sand, which is found to have as good an effect, and requires no previous calcination necessary in flints, that they might be pulverized, in order to their being mixt with the other ingredients. The finest Venetian glass was also made with calcined flints.

The proportion for this finest Venetian glass is set down by Antonio Neri to be thirteen parts of the fixt salt to twenty of the powdered flint,
that

that is about two parts of the salt to three of the flints. In the making all glass it is usual to mix a great quantity of old glass with the fresh materials, as this addition much facilitates the melting. In bottle-glass, they put in old glass and fresh materials in equal proportion.

All glass is disposed to have more or less of a greenish hue: this is taken off from the fine glass by adding to it a small portion of a stone found in Italy called manganese. Writers in Latin call it *magnesia*. Agricola mistakes it for the magnet or load-stone.

Flint-glass does not acquire this green hue. Therefore no manganese is used in it.

Some plants, which grow on the sea-shore, contain in their ashes, besides the alkaline salt, which they have in common with others, another salt, which will not unite with sand, as the alkaline salt does; but, when salt is made with any of these ashes, it flows melted on the top, and is taken off with ladles, before the glass is wrought, this is called sandiver.

One use of calcining stones is to fit them for glass, though now this practice be laid aside for the reason before mentioned. Another effect from calcining many stones is a power they thereby receive of attracting water very strongly.

Ala-

Alabaster fresh calcined attracts water so strongly, when wet with it, that it unites again into a hard and firm stone. This is the preparation called plaister of Paris. At length the calcined stone by gradually imbibing the moisture of the air is in some measure saturated with water, and then the action between it and the water becomes faint, and it will not harden, as it does when newly calcined.

Stones are in general to be divided into two classes; such as melt with fixt salt into glass, all which will strike fire; and such as will not vitrify, and these burn into lime. The earthy part of animal and vegetable substances resembles this latter kind of stones.

Lime, which is made either by calcining chalk, or by the calcination of particular stones called from the use of them, lime-stones, attracts water so strongly, as in action to excite a great heat.

The effect of the phosphorus made with alum seems in part to arise from the same principles; the stony part of the alum calcining into so subtle a lime as to heat enough by the mere moisture of the air, to set fire to the oily or sulphureous part of the other ingredient, whose inflammability is heightened by the acid spirit of the alum, which joining with the oil of the other in-

ingredient composes a very inflammable sulphur. From the materials of the phosphorus mixt I have sublimed yellow flowers like those of brimstone.

Lime is of a nature analogous to fixt alkaline salts, but more exalted in its force. It does not intirely dissolve in water, as the salts do ; but only communicates some of its subtle parts to it. Hence is produced a very valuable remedy called aqua calcis, described in the London dispensatory.

Again lime is made use of to increase the caustic quality of the fixt alkaline salts. This it does by its powerful attracting humidity. It is by this power of attracting all moisture, that the fixt alkaline salt itself is a caustic. It acts not on a dead body. But in a living one, where the humours are fluid ; by drawing strongly all moisture out of the fibres, it dries them up with a quickness of action, resembling the effect of an actual fire ; this when assisted with lime, they perform very strongly ; alone their power is more languid.

The caustic usually called lapis infernalis is made by evaporating the soap-boilers ley, till it will coagulate, when cold, into a brittle substance ; but care must be taken, that the ley be not boiled further than is necessary for this purpose.

The

The heat may be continued, till it is reduced to a dry salt.

This preparation must be kept in a glass well stoppt, it being greatly disposed to liquify by the air. This readiness to liquify creates an inconvenience in the use of this caustic, by rendering it difficult to confine it to the limits, wherein its operation is desired: for this reason it has given place in use to another caustic not so subject to this imperfection, which is prepared by forming a paste with a very strong ley and lime a little but not much slacked.

As lime bears a resemblance in its nature to the fixt alkaline salts; so its action on sal ammoniac is much the same with the action of an alkaline salt upon that substance; for being mixt with it, and distilled by the like process as with a fixt alkaline salt, a volatile spirit is here also produced; but one that is much more acrid and penetrating, than when the alkaline salt is made use of.

If sal ammoniac be mixt with fine chalk or whiting, a volatile salt will be raised in a solid form. This process requires a strong fire, the preceding one is performed with a gentle heat.

When lime and sal ammoniac are mixt together, the volatile vapour ascends and strikes the nose immediately; but when uncalcined chalk is

is mixt with the salt, no such effect follows; that the volatile part may be separated, a strength of fire, which may give the chalk some degree of calcination is requisite. But where perfect lime is used, the active parts of the salt are so divested of the grosser earth, that no salt in a solid form can be obtained.

Lime seems to have a similar effect also on fixt alkaline salts; for in the preparation of the lapis infernalis, the quantity of the production falls considerably short of the salt, from which it is prepared.

Some have scrupled to call these spirits, thus drawn with lime, alkalis, because they do not make so visible an effervescence with acids, as those do, which are drawn with fixt salt. But if the fixt salt itself be highly calcined, the spirits drawn with it will have no more visible fermentation, than those have, which are drawn with lime.

Equal parts of quick-lime, sal ammoniac and sulphur being mixt together yield a spirit, which whenever open to the air emits a fume without ceasing, which is extreme subtle and penetrating.

Orpiment, which I observed at our last meeting to belong to the class of sulphurs, infused a little while in hot water, with double its quantity

tity of lime, impregnates the liquor with the most penetrating fume known.

Lime also dissolves oils very powerfully ; for this reason it is used in making soap to facilitate the uniting of the oil with the alkaline salt. The common soft soap has a mixture both of oil and tallow. In preparing it the soap-boilers first make a ley by pouring in water upon layers of pot-ashes and lime warm from the kiln strewed in a shallow pit interchangeably. They take care that the ley be not too strongly charged with the salt. This they judge of by the weight of the liquor. With this ley they first boil the tallow ; as soon as these boil up together, they add the oil, and immediately damp the fire, that the mixture may stand in digestion three or four hours, in which time the oil, tallow, and ley become united into one uniform substance : and this by boiling they gradually bring to the common consistence of soap. When this soap is first made, it appears uniform ; but in about a week's time, the tallow separates from the oil into those white grains, we see in common soap.

Soap thus made would look yellow, but by a mixture of indico added at the end of the boiling it is turned green, that being the colour,

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which

which results from the mixture of yellow and blue.

Oil will not join thus completely with a ley made from any of those ashes, which I observed before to contain a salt, that does not incorporate with the glass made from such ashes. But however the oil by repeated or long continued boiling with such a ley will gradually imbibe from it its alkaline salt, and be converted into a soap, which, when cold, concretes into a solid consistence.

Hard soap may also be made with a ley, wherewith oil will perfectly unite. For this purpose common salt is made use of. When oil or tallow has been united with the ley, after a little boiling salt is thrown in upon it, which readily dissolving in water, but not in the oil or tallow, draws the water in great measure out, so that the oil or tallow united with the salt of the ley swims on the top.

Water impregnated with lime is made use of for refining sugar upon the same principle of its dissolving oils. Coarse sugar being boiled in lime-water perfectly dissolves in it, the gross oily part, as well as the sweet part, which constitutes the sugar. When the whole is by this means reduced to a uniform syrup of a proper consistence,

ence, it is set by in a heat sufficient to keep the oily part fluid, that the sugar may separate from the syrup by a kind of chryftallization, as salts shoot in water, that is charged with them to a certain degree.

To render this separation more effectual moist clay is spread over the sugar, when the sugar begins to cryftallize, that the sugar may gradually draw in the moisture from the clay, and the oily part by that means be more effectually expelled: for sugar unites itself with water much more freely than with oil; so that when water is present, it will draw that in with force enough to expel the oil.

When the sugar is brought near to a perfect fineness, it will unite entirely with water without the help of lime; therefore in preparing double refined sugar lime is not used.

Lime seems also to have some effect on the acid part of the juice of the sugar-cane; for it is used in the first making of sugar, lime in substance being put into the juice before boiling; but in a very small quantity, scarce above the measure of half a pint of powdered lime to three hundred gallons of juice, which shall make as many pounds of sugar. Here the lime seems to produce at once the same effect as time will occasion without the assistance of any art. The

sugar we see adhering to raisins candied is only their juice concreted into that form. In the richest kind of sugar-canes the juice, which exudes from accidental fissures in them, will concrete into sugar by the heat of the sun. Perhaps this was the only sugar known to the ancients.

(Here a sugar-mold shewn.)

Lime is also made use of to dissolve sulphur in the preparation of what has been called lac sulphuris, but in our present pharmacopœia sulphur precipitatum. A quantity of sulphur being boiled with three times its quantity of quicklime, till the sulphur is dissolved, and the decoction filtered; upon the affusion of any acid spirit, the liquor turns to a milky whiteness, and deposits a powder, which is to be washed frequently in warm water, till it has lost all its acrimony.

Calcined chalk impregnated with the acid spirit of nitre will produce a kind of phosphorus not always shining in the dark, as the phosphorus from urine does; but immediately after it has been exposed to the light of the day or the beams of the sun it shines, if it be forthwith removed into a dark place. This is the phosphorus of Balduinus. There is a stone found near Bononia in Italy, which being

ing calcined only, exhibits the same phænomenon.

The most convenient method of preparing the phosphorus of Balduinus is this.

First let good chalk lime be powdered, and put by degrees into the strongest spirit of nitre, that can be prepared after Glauber's method, till such times as the spirit is saturated, and all effervescence ceases.

This compound being diluted with a quantity of water, and filtered; the liquor upon evaporation shews, that the acid spirit has converted a considerable part of the chalk into a salt. From this salt the phosphorus is thus to be prepared.

Provide a shallow earthen dish made of an earth, that will endure the fire; place it in a fire, till it is red hot. Then throw into it of the fore-mentioned substance reduced to powder by little and little. As soon as ever a quantity is thrown in, it boils up; and the success of the process depends upon throwing in a fresh quantity, before the boiling up of that last thrown in is quite over. As soon as the last parcel is thrown in and melted, the dish is to be removed from the fire, and placed, before it is cold, under a glass, which

must be well cemented down to keep out the air.

The most commodious method of placing the dish in the fire is under a muffle in an essay-furnace.

A

COURSE of CHEMISTRY.

PART IV.

METALLURGY.

LECTURE XVI.

OF the substances, that are dug out of the earth, such of them, as melt in the fire, we have observed to be called minerals, the rest being only named fossils.

Minerals that afford metallic substances are usually called ores: these are the next subject of our inquiry. Metallic ores are of two kinds; for some afford a perfect metal, from others can be separated only a metallic body, not having the perfect form of a metal. The characters,

acters, by which metals are distinguished from other bodies, are being fusible and malleable. That is, whatever substance melts with heat, and ductile under the hammer, when cold, is properly called a metal.

The metallic bodies, to which these characters agree, are lead, tin, iron, copper, silver, and gold. Of these tin is the lightest in weight, and gold the heaviest; the next to tin in specific gravity is iron, then copper, after this silver, then lead almost of the same weight with silver, and gold greatly exceeds the weight of any of the rest. The imperfect metals are quicksilver, bismuth, spelter, and a metallic substance separable from the mineral called antimony. Quicksilver differs from those properly called metals, by its perpetual fluidity; the rest, which are solid, by the want of malleability, though they have an external appearance, and weight resembling a true metal, and are fusible in the fire.

In order to understand the true intention in each part of the processes, by which metals are separated from their ores, it is necessary to have some knowledge of the nature of the metals. This is best obtained by calcining them.

It is well known, that metals, not only when melted, but when heated in the fire are soon covered

covered over with dross. Lead or tin melted, their surface at first appears of a shining brightness, but is presently sullied with a dim skin. If this be removed, it is soon succeeded by another. Iron or copper, when made red-hot, cast off brittle scales. The metals kept long in the fire will by degrees waste thus wholly away into dross. This is called calcining them, and the friable substance, into which they are thus reduced, the calx of the metal. This calx is specifically lighter than the metal. There is besides an accession of new matter. Lead when calcined into that red powder called minium and red lead, gains about a twentieth part in weight. Lead and tin easily melt, and being stirred about, while they remain melted, soon are reduced into powder; and this powder by being longer in the fire will change from its first colour, till in tin it becomes white, in lead red, whence minium or red lead so called.

The process, whereby minium is made, is this. The lead is placed in a reverberatory furnace, where with a due degree of heat and stirring, it is reduced into a greyish dross. The particles of this dross often contain in them some lead uncalcined. To separate the calcined part this dross is ground in a mill with water. During the grinding the water carries

ries out of the mill all the fine drops. The rest which is imperfectly calcined subsiding. This residue is calcined and ground afresh; till no more gross parts subside. The fine drops thus obtained, is placed again in the furnace, and a proper heat raised upon it, whereby it gradually changes its colour, till it becomes red. The reverberatory furnace here used is so contrived, that the heat may be equal on every part of the matter. Therefore here two long fires are made use of, one on each side of the matter.

(Here shew the red-lead furnace.)

Iron and copper are best reduced to a calx by being kept for a length of time red-hot: for thus scales will continually cast off from them. If the metal be reduced into very small parts, before it be exposed to the fire, these scales will be generated quicker than otherwise, the surface of the metal being increased.

Silver and gold bear the fire to that degree, as to suffer no change by the longest continuance in the hottest fires we can make by any fuel. However these bodies are not absolutely indestructible by intense heat; for burning-glasses have been made to collect the sun-beams so strongly, as readily to reduce both these metals into a calx. Mons. Homberg prosecuted this experiment very fully with a glass of the
late

late famous Duke of Orleans. Several years ago we had here in England a metalline concave brought hither by the maker, Monf. Villette, which produced a degree of heat still more intense than the burning-glass, which Homberg made use of; but the sun's rays being in that collected by refraction, and the rays descending upon the subject to be examined, the subject could be more commodiously kept in the focus for a length of time, than can be done in reflecting metals, where the rays ascending upwards will be intercepted by any body, whereon the subject examined can be laid. In these metals therefore the subject can only be kept in the focus, till it is melted; and it was surprising to see how soon the mirror of Monf. Villette melted down the hardest bodies, and those, which indure the longest in our most intense fires. Monf. Homberg by his glass found, that gold, when exposed to a heat strong enough, was affected like other metals, and burnt like the rest to a calx.

But as gold is not to be moved at all by our fires any farther than to be melted, so quicksilver with a moderate heat evaporates. But if quicksilver be put into a glass, and exposed long, to a less heat than what will evaporate it; in length of time it will be reduced to a red powder,

powder, which has usually been called *Mercurius præcipitatus per se*; but is now by the college stiled *Mercurius calcinatus*.

The calx of lead is called by different names according to the degree of calcination it has undergone. When calcined till it is become red, it is called *minium* or red lead, as has been already observed. The calx of lead acquires this colour, not by the violence, but long continuance of the fire.

When lead is burnt off from silver or gold in order to separate those metals from it, (the practice of which will be illustrated hereafter) it suffers a greater heat, but not so long continued. After this calcination it is called *litharge*. It does not here acquire so bright a colour, but *litharge* will receive this colour and become *minium* by a long calcination.

Litharge has been distinguished into two kinds, *litharge of gold* and *litharge of silver*, as if the metal, from which the lead was burnt, made a difference in the *litharge*; whereas the *litharge* is simply lead calcined, unless when it is mixt with a small quantity of what other base metal, may have rendered the silver and gold impure. However *litharge* is seen of two colours, which arises only from this. As it falls from the furnace, it concretes into larger lumps, the

the outside of which to some depth in cooling becomes of a pale colour, the inner part being red.

Lead and tin calcined together in the proportion of two parts of lead to one of tin makes a white powder called by workmen putty, and is used in polishing metals. This is not the putty of the glaziers. That is whiting with or without a little white lead wrought into a paste with linseed oil.

Lead, when calcined, will dissolve in oils, as is seen in making the plaisters, which have calcined lead in their composition; such as the common plaisters, which have gone usually under the name of the diachylon, emplastrum e minio, &c.

Iron, calcined till it becomes red, was the *crocus martis astringens* of the London pharmacopœia. But scarce two authors agree in their account of the preparation of this medicine. There is another *crocus* of steel called *aperiens*, which we shall mention hereafter. This also has almost as many processes for its preparation, as there are authors, who describe it. Nay what in some authors is called *crocus aperiens*, is called by others *astringens*. Nor is it easy to assign any great difference between them in their operation however prepared: they are all the
calx

calx of iron. Our chemists at present sell the colcothar of vitriol for both.

The calx of lead by a strong heat will again melt, and become a reddish kind of glass. This glass will incorporate with sand. If three parts of litharge be melted with one part of white sand, it makes what is called *vitrum saturni*, or glass of lead, and is a preparation useful in treating silver and gold ores.

That called flint-glass is a composition of fine white sand, nitre, and lead. They do not put lead in its metallic form into their pots with the other ingredients, because upon its first melting it would sink to the bottom and corrode the pot, so as to eat holes in it. They therefore use either red lead (the preparation of which I have just now described) or white lead; the process for making which will be explained hereafter, or both together.

Nitre and sand without any farther addition will make a fine transparent glass; but it is not durable: it will soon be full of little flaws, called by the workmen *crizzling*. The addition of lead preserves the glass from that defect. When this glass was first made in England the proportions observed were one part of lead, two of nitre, and about three and an half of sand. But this glass after a course of years became subject

to the forementioned defect. More lead is now employed; though if too much be used, it gives the glass a blackish hue; and likewise arsenic in a small quantity is added to the composition.

The yellow and red glazing of earthen ware is litharge spread over the vessel already burnt, and then melted upon it into glass, by a second burning: the colour is yellow or red according to the earth it is burnt upon. The litharge is spread upon the vessel by this means. The litharge is ground with water, till it is reduced to extreme fine parts, and mixt with the water to some consistence; into this mixture they dip the vessel. The water soon soaks into the burnt earth, and leaves the litharge evenly spread over it.

The black glazing is performed in the same manner with that kind of lead ore, which breaks in large flakes, and is on this account called potters ore.

(Here the model of the potters furnace.)

White glazing is composed of three parts lead and one of tin calcined together. Then melted into an opaque kind of glass with sand and the ashes of the sea-weed called kelp, this glass being ground with water and laid on, as the other glazings are.

Thus

Thus our fires easily vitrify the dross or calx of lead; but are scarce strong enough to melt perfectly the calx of any other metal. Our fires will also vitrify the metallic part of antimony. If the mineral be roasted with a gentle fire, at first it smokes; when this smoke ceases, if it be melted, there separates a metallic part: (other methods of obtaining this metallic part will be shewn hereafter,) but here if the roasting be longer continued with a fire gradually increased, and at length the mineral is melted for a due time, a glass is produced, which has been used in medicine, and is a strong emetic.

However the burning-glass before mentioned would not only turn gold into a calx, but even melt that calx into glass.

The experiments that were made with that glass upon metals, illustrate greatly the nature of those bodies.

When gold or silver were held in the very focus of the glass, after melting they were dissipated in small grains, which being collected, appeared to be minute globules of metal nothing altered, just as we shall find quicksilver to be dispersed by our fires. At a small distance from this place of the intensest heat the metal smoked much, and a powder soon gathered upon the substance of the metal, which in gold would

would melt into a little speck of glass, and run off from the metal, leaving the surface of the metal bright, which would soon be covered again with fresh calx, and that melt again into another speck of glass as before. The calx produced upon the surface of silver would not melt, but lay spread over the metal in the form of a fine dust, gradually increasing. If the silver had been melted with antimony, there would appear a vitrification.

If the silver or gold were held still a little farther from the focus; it only smoked and wasted very slowly without calcining at all.

In all these experiments the metal was held to the glass lying on a piece of charcoal.

If any of the other four metals lead, tin, copper, or iron, were held to the focus of the glass upon a test made of bone-ashes, they soon calcined. Lead, quickly after its calcining, vitrified. Tin would scarce vitrify at all. Copper vitrified completely. Iron almost, but the substance it lay upon melting at the same time hindered the prosecuting of the experiment to so perfect a vitrification, as was effected in copper. All these calxes, even when vitrified, upon being laid upon a piece of charcoal in the heat of the focus soon returned again into metal. All these metals if laid upon charcoal in the heat of the fo-

cus smokt, and wasted very fast, but would not vitrify at all, except iron, which sometimes would begin to vitrify, when the coal was so burnt, as to be turned to mere ashes to a good depth under the iron.

Iron exhibited several particular appearances. Before it melted a black pitchy substance fried out of it. This the experimenters call the sulphureous part of the metal. But it lay upon the metal without burning. If we consider the manner, in which iron is produced from its ore, I think we may form a better opinion of this substance. In making malleable iron the last remains of the dross, or cinder, as the workmen call it, are hammered out. This dross is black, as they describe the substance, that fried out of the iron before the burning-glass, and is more fusible than the metal. Without doubt therefore this substance was a little remains of this dross left in the iron.

As soon as the body of the iron melted upon the charcoal, it sputtered very much, and would waste all away in fiery sparks, except in the fore-mentioned case, when a large bed of mere ashes gathered under it; but if ever it ceased from sparkling by that means, by shaking the coal, and thereby removing those ashes, the sparkling would return again.

Iron

Iron upon the test did not sputter at all, except it had first been melted upon charcoal; then upon a test it would sputter all away.

If the iron, after its being vitrified, were laid upon a piece of charcoal in the focus of the glass, it continued quiet for some time; but at length it would begin to sputter. Then being removed it appeared no other than melted iron.

Thus we see the inflammable body, charcoal, restored to metals their form, after their malleability and other proper characteristics had been destroyed by calcination; as if the coal supplied the metal again with what, the great heat of the glass had deprived them of.

In the same manner litharge and the calx of tin heated red-hot in a furnace, soon return again into their respective metal upon being mixt with charcoal, tartar, sea-coal or any other inflammable substance. But the heat, wherein this operation is performed, must be greater, than what would melt those metals. Even out of flint-glass the lead may again be recovered by this means, if the glass be mixed with a quantity of a fixt alkaline salt to render it more fluid.

The scales of copper also, though not so easily reduced as litharge, yet the operation may be

effected with a strong fire by the addition of an inflammable substance.

The scales of iron are not easily reduced by our fires. It has been attempted at the furnaces, where iron is smelted, without success. This is owing to the difficulty, wherewith iron melts. For in the other metals a greater heat is required to reduce the calx, than what would melt the metal. The fore-mentioned burning-glass would not give heat enough to reduce the calxes of gold and silver.

All these effects shew, that there is in metals an inflammable substance ; the imperfect metal called spelter flames in the fire upon being melted. But though this appearance is seen in no metal, yet iron, when brought to a very intense heat, will not be cooled by blowing air upon it, but be brightened by it, as if farther heated by the blast after the manner of inflammable substances ; also as nitre has been shewn to increase the inflammability of burning bodies very much, so the two lightest metals tin and iron, by being mixt with nitre, will send out a very bright flame.

Farther, though nitre will not cause lead to flame, yet it will suddenly produce in it the same effect as a strong action of the fire : for if nitre be melted by a strong fire, till it is red-hot,

hot, a lump of lead thrown into it will suddenly be calcined by it.

But there is also another effect in the calcination of metals, which deserves our enquiry : this is whence their calxes should receive the additional weight they acquire ; this being an effect not peculiar to red lead only. I think we may safely answer, that it is from the air. I had occasion to take notice toward the beginning of these lectures of the strong action, there is between inflammable substances and the air. When any body burns under a close vessel, till it is extinguished, a considerable quantity of air is found to have lost its elasticity. This effect, compared with the present observation upon the calcining of metals, points out to us pretty plainly, whence the calxes of metals receive their additional weight, and what becomes of that portion of air, which seems to be consumed by burning bodies. Without doubt, while the air by acting on the inflammable substance either in metals or other bodies expels it from them, it unites itself (in part at least) to the remains of the body.

When red lead is reduced again into lead, it not only loses all the increase, it has acquired, but likewise falls short of the original quantity, shewing how much of the lead has fumed away in the calcination.

In calcining the metals care is always taken to have a free access of the air to them. Hence it is, that in calcining quicksilver a pipe is inserted into the containing-glass open at the bottom by a small orifice, to preserve a communication with the external air.

However, to render this matter still clearer, it may be proper to consider distinctly this question, whether metals are reduced to the form of a calx, only by this new matter added, joining with the metallic particles, or whether they do not also lose something from themselves? and, when metals are recovered from their calxes, whether it is effected by the inflammable substance put to them supplying them with something the fire has robbed them of, or only by assisting the fire in separating the adventitious matter joined to the metallic particles?

It is evident, that all the adventitious matter gained upon calcination is dislodged again upon the reduction of the metal. And, that the metal also receives something from the substance joined with it, is, I think, manifest from the experiments above related.

The four metals lead, tin, copper, and iron, while lying on charcoal, would not calcine, excepting iron only in one circumstance, where it was in the same case, as if it had not laid upon

a coal, but upon a substance not inflammable. Now in this case the calcination could be hindered no otherwise, than by the coal's supplying the metal with something, which the heat took from it. In iron it is still more manifest than in the rest, that the metal imbibed something from the coal, from that faculty of sputtering, which it acquired by being melted on it; for it would afterwards sputter, though removed upon a test. After it had been calcined, being laid upon a piece of charcoal the iron lay quiet for some time; but at length would begin to sputter; and then was become iron again. Silver and gold calcined even upon charcoal in a certain degree of heat; but with a less heat they would not calcine, but waste in fume, as the other metals did. When they calcined, I suppose, the charcoal could not supply them fast enough, with what that great heat wasted.

What metals received from the charcoal, appears to be the principle, to which it owes its inflammability; for the coal burnt to ashes faster under one than under another. Iron consumed it faster than the rest, as by the sputtering of it, it appears to have imbibed more freely than the rest.

Hence upon the whole we may conclude, that metals may be analyzed into two different sub-

stances ; one whereon the body and substance of the metal depends, the other to which is owing the metallic form. This last appears to be that principle common to all inflammable bodies, to which they owe their power of burning, and therefore is in all metals the same ; but the other must be different to constitute the distinct specific qualities of each metal. These two are the sulphur and mercury of the ancient adepts.

LECTURE XVII.

HAVING thus discovered the constituent parts of metals, before we proceed to the operations on their ores, it will be requisite to shew the action of acid spirits, and salts upon them ; for such substances are mixed with them in the ore.

And these acids may be considered in a two-fold respect, either when joined with water, and constituting an acid spirit ; or when united with terrestrial substances, as in solid salts.

Now I shall consider the acid spirits.

By two of these all metals may be dissolved. Spirit of nitre alone will dissolve silver, copper, iron, lead, and quicksilver, and by the addition of spirit of salt the other two metals gold and tin.

This mixture of the spirits of nitre and of sea-salt, called aqua regia, dissolves all the metals except silver ; and spirit of sea-salt alone dissolves all but gold and tin.

In the action of acid spirits upon metals and metallic bodies there are three remarkable differences to be observed. Sometimes the acid spirit

spirit so acts upon the metal, as to receive it into itself, that they become together one fluid body, and, if any quantity of water be added to the spirit thus impregnated, the metal still remains suspended, and is diffused throughout the water, as it was before in the spirit. Of this kind is the solution of silver, copper, quicksilver and other metals in spirit of nitre. In some instances the metal is only corroded to powder, and not joined with the spirit. This is the case of tin with spirit of nitre. There is likewise a third circumstance, where the metal is received into the fluid, but it will not join with an addition of water. Upon the affusion of water a precipitation is made. This is seen in tin, that has been dissolved to saturation in aqua regia.

In the first case the acid of the spirit by uniting with the metal has converted it into a true salt. If the spirit by the help of heat has taken up a large quantity of the metal; the metal will shoot, when the spirit is become cold, after the manner of a salt. These crystals dissolve in water like salts. By a force of fire they gradually part with so much of their spirit, till they become indissoluble in water; which is also the case of other salts. Their becoming indissoluble by losing a part of the adhering acid, shews the dif-

difference between these metals and those, which are only corroded by the acid spirit. These, which are only corroded, do not receive originally so much of the acid, as the other metals do. That these metallic crystals are rendered indissoluble in water by losing part only of their acid spirit, is manifest, because they remain of a greater weight than the original metal, whence they were made, and by a longer application of fire they will still continue to part with more of their acid spirit, after they have been brought to the condition of being indissoluble in water. The greatest part can scarce be brought to part with all their acid spirit by heat alone, however intense: but they require also the addition of some inflammable substance.

Thus the case, where metals are only corroded by the acid spirit, differs from the other solely by the quantity of acid, that unites to them. The third case, where water precipitates the metal, is a medium between the other two. Here the metal has associated itself with only such a portion of acid, as limits the quantity of water, with which it can unite itself.

Where the metal is only corroded, some portion of the watry part of the spirit seems to be united with it, though not enough to make the
mass

mass fluid; for by distillation a portion of acid spirit may be driven from it.

If silver dissolved in spirit of nitre, after evaporation of the spirit, be just melted (which is done with a small heat) it makes the lunar caustic. The acid particles of the spirit, by being joined with those of the silver, give the mass a very corrosive quality.

This mixt with salt, and rubbed upon brass will cover it over with a crust of silver. This is the means, by which the dial-plates of clocks are silvered.

In all the fore-mentioned processes of evaporating the menstruum from a metal, it has dissolved, the metal left behind retains still so much of the acid spirit, that it does not yet appear in its original form; but melted with any inflammable substance, or with an alkaline salt, not too highly calcined, it returns again perfectly to its metallic form.

Metals may be recovered from the menstrooms, that have dissolved them, not only by evaporation of the menstruum; but by other means also, viz. by precipitation. This is done by putting to the spirit some substance, between which and the spirit there is a stronger action, than between the spirit and the metal already dissolved in it.

In the first place some metals precipitate others. If a plate of copper be put into a solution of silver, the silver will fall to the bottom of the containing glass, and the spirit will act on and dissolve the copper. Iron will precipitate copper, and lixivial salts precipitate this metal, as it will any of the metals directly; and then the menstruum becomes no more than nitre dissolved in water, as we have before shewn.

In some of these precipitations the powder, which falls to the bottom, is pure metal; and by melting may be formed into a mass, in others the precipitating substance joins with the metal.

Silver is precipitated out of copper unmixed, especially if a little heat be applied, that the menstruum may act with full force on the copper. Copper will also precipitate gold pure out of aqua regia, and iron precipitates copper in the same manner from spirit of nitre.

On the other hand, tin put into aqua regia, that has dissolved gold, makes a precipitation of the gold, but united with some portion of the tin. The lixivial salts precipitate none of the metals pure. Gold thus precipitated falls in a powder called aurum fulminans, because, if gradually heated, it explodes like the pulvis fulminans, I have before shewn you.

Like-

Likewise as silver does not at all dissolve in aqua regia, so common salt, or its spirit put into a solution of that metal in aqua fortis precipitates the silver, but not in its metallic form; to restore that, the precipitation must be melted in a crucible, being first covered with some alkaline salt. By this method silver is obtained exceeding pure; for no gold will be retained by the aqua fortis, and when the salt is added, the aqua fortis is not disqualified from retaining all other metals except the silver.

As silver does not at all dissolve in aqua regia, nor mercury so freely, as in spirit of nitre; common salt put into a solution of these metals in spirit of nitre precipitates them; but not in their pure metallic form. The precipitation of quicksilver by common salt or spirit of salt makes mercurius precipitatus albus, and the precipitated powder by washing in much water is freed from the acid spirit loosely adhering.

There is another method in use for making white precipitate, from the composition, hereafter to be described, called corrosive sublimate. This is performed by dissolving equal quantities of pure sal ammoniac and this corrosive sublimate in water; and then making a precipitation with a solution of a fixt alkali salt.

But

But I have now described the most usual operations upon the metals by the acid spirits of nitre and of common salt, except only the use made of these spirits by the refiners of silver and gold. I have before shewn, how all other metals are separated from these two. They are best separated from one another by these spirits. When silver is dissolved in spirit of nitre; if any gold were in the silver, it will lie at the bottom in the form of a black or purple powder. In like manner, if gold containing silver be dissolved in aqua regia, the silver will be left in a white powder.

If these two metals are mixed in equal quantity neither of the spirits will act upon the mass: and if the predominant metal be not above three times the weight of the other, the acid spirit, by which that metal is dissolvable, will eat it out of the composition without destroying the form. This enables the essayers to perform an essay with great exactness in a very small quantity. They usually take about six grains only of the gold to be essayed, and refine it upon a test with about thrice its weight of silver; then beat the mass into a thin plate, and put it into aqua fortis, which eats out the silver, but leaves the plate intire, though brittle. By the plates keeping thus intire they are secure

cure against losing any minute portion of gold, which might falsify the essay. To be secure of extracting all the silver, a second quantity of aqua fortis is to be poured on the plate, when the first has done its office, and the plate at last washed with clean rain or river water. But as the plate will still look of a brown colour, before it is weighed, it is to be brought to its colour by igniting it with a degree of heat not sufficient to melt it.

Thus much concerning the acid spirits of salt and of nitre. The other two acid spirits deserve also to be considered.

By dissolving iron with oil of vitriol is made the medicine called sal martis; by its corroding quicksilver turbith mineral.

If filings of iron be put into oil of vitriol diluted with three or more times its quantity of water, a strong ebullition will arise, and the liquor become green.

If the flame of a candle be applied to the fume, which rises, while the metal is corroded, it takes fire. This is an instructive experiment; for it shews us, that in the vapour which rises from acid spirits, while they corrode metals, a part at least of the sulphur or inflammable substance lodged in the metal is carried off into the air.

If this sal martis be kept in the fire in a crucible, till it becomes red, it makes a crocus martis. If this crocus be exposed to a moist air, it will flow in it; and make what is called (though improperly) oleum martis per deliquium.

Oil of vitriol will also corrode lead in a small quantity; copper it will dissolve; upon the other metals, it will have no effect.

Copper, iron, and lead will dissolve in vinegar, also tin, when calcined.

If tin calcined be dissolved in distilled vinegar, and the dissolution in part evaporated, and set to shoot, the salt resulting is called salt of tin or sal Jovis. In order that the vinegar may act on the tin, it ought to be very highly calcined, by being for a long time exposed to the action of a strong fire.

Lead, or any calcination of it, being boiled in vinegar, till the vinegar becomes sweet; then the liquor evaporated in part, and set to shoot, affords a salt, which on account of its taste, is called the sugar of lead, or saccharum saturni.

Lead corroded by the fumes of vinegar becomes cerusse or white lead. The method of preparing cerusse is this. They fill pots in part with vinegar; then they roll up thin plates of lead and put them into the pots. By the shape of the pots the lead is kept up

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from

from touching the vinegar, and the pots are also covered with a plate of lead. These pots ranged in rows they bury in horse-dung, by the heat whereof the steam of the vinegar rises up and corrodes the lead, so that its surface becomes covered over with cerusse. After a time they beat off the flakes in a mill with stampers, then wash the powder in water to separate its gross parts.

Filings of copper give vinegar a fine green tincture; which being evaporated in part will shoot into green crystals, which are verdigreese. In Provence verdigreese is made by stratifying plates of copper with the husks of the grapes, after their juice is pressed out for wine. These, with the addition of some wine, corrode the copper, and turn it into verdigreese.

If the spirit of nitre, wherein quicksilver has been dissolved, be evaporated, a white substance is left, which by a farther degree of fire turns red, usually called mercurius precipitatus ruber, but in the present pharmacopœia mercurius corrosivus ruber, of excellent use in surgery. This freed, from what acid particles loosely adhere to it by often washing, is called arcanum corallinum. Some burn spirit of wine upon it. The reason of this operation will be readily understood from the process we

formerly shewed of dulcifying spirit of nitre by mixing it with spirit of wine.

If filings of iron or steel be boiled with an equal weight of tartar, they will be corroded by the acid of the tartar, and make the chalybs tartarifatus of Bates.

If these filings mixt with twice their weight of tartar, be formed with a little spirit of wine into a paste and laid by to ferment for three or four days; and this process be repeated four times or oftener: two ounces of this steel tied up and suspended in a pint of spirit of wine will impart to it a styptic quality. This is the invention of Helvetius. But the process being tedious, the college have substituted another in its stead.

The imperfect metals also are acted on by acid spirits.

The magistery of bismuth is prepared by dissolving bismuth in spirit of nitre, and precipitating it by diluting the solution with a quantity of fair water.

LECTURE XVIII.

BESIDES the acid spirits, solid salts by virtue of the acid in them have very remarkable effects upon metals, and metallic bodies. These we shall now proceed to consider.

Corrosive sublimate is made by mixing quicksilver with the gross body of salt, and of nitre, with the addition of calcined vitriol and subliming the composition. What sublimes is the corrosive sublimate. Calcined vitriol alone with quicksilver will not make this sublimate. Its use is the same as in making aqua fortis, only to disengage more easily the acid spirits from the other salts.

This composition is made also use of in purifying gold, and in particular is useful to remove the last remains of any mixture, that may render the gold brittle. But gold may be refined by this sublimate alone; if, while the gold is in fusion, fragments of sublimate are successively thrown in upon it.

The reason for this effect of sublimate may be learnt from experiments, Mr. Boyle made with it. He laid plates of copper upon sublimate

mate in a retort and distilled it off from them. He made also the like experiment with silver and gold. By this process the gold was not sensibly changed, but the copper and silver were so acted on, as to be reduced into a kind of rosin, which laid upon live coals would burn away with a flame.

If tin be mixt with an equal or double quantity of sublimate, a liquor will distil from it, which Mr. Boyle makes particular mention of on account of its remarkable fuming.

In corrosive sublimate so great a portion of acid is united with the quicksilver, as to render it dissolvable in water. That the quantity of acid adhering is the cause of its being thus dissolvable, is manifest, because by only adding more quicksilver to the composition, as is done in making mercurius dulcis, the compound becomes indissolvable in water.

This corrosive sublimate now described, by the violence of its acrimony is one of the most destructive of poisons; but when mixt with a fresh quantity of quicksilver, after the rate of four parts of sublimate to three of fresh quicksilver, and sublimed again it becomes milder than before. By subsequent sublimations without the addition of more quicksilver it grows still less acrid. The third sublimation makes

it a medicine very safely to be used internally, only stimulating very gently the bowels. If the sublimation be repeated five or six times, it is still softer.

This preparation, to distinguish it from the preceding corrosive sublimate, is called *mercurius sublimatus dulcis*, and more briefly *mercurius dulcis*.

At the first sublimation a greater quantity of quicksilver being united with the acid of the sublimate, that acid is in part buried in the quicksilver. And further, at each subsequent sublimation a part of the acid is always expelled; for every time there rises into the neck of the bolt-head an acrid part to be separated from the rest. Therefore after every sublimation the preparation contains a greater portion of quicksilver in respect of the acid, than it had before. And thus, by being charged with an additional portion of quicksilver, it is rendered indissoluble in water, and so much less capable of acting on our bodies, as from a deadly poison to become a medicine only gently stimulating.

With corrosive sublimate an eminent operation is performed upon antimony. If these two substances are mixt together, and distilled, there arises an unctuous congealed substance, called the butter of antimony. Many cautions are
given

given by authors in regard to this distillation. That the retort be large enough to contain four or five times the quantity of the ingredients put into it; and that it be provided with a wide neck, lest the butter should rise so fast as to obstruct it, and breaking the vessel endanger the life of the operator from the fumes, which would be emitted. But the process is daily performed with great safety in the retorts made at our glass-houses, whose necks are always too large to be choaked up, though the retort be competently filled with the materials; provided only that the butter be melted down by approaching some hot body to the neck of the retort, where the butter lodges.

As soon as coloured fumes appear, the operation should be stopped, that the butter, which is come over, may not be discoloured by them. From what remains in the retort may be sublimed a substance of a red but somewhat dull colour, which is the true cinnabar of antimony. The quantity of this cinnabar is somewhat uncertain, depending upon the quality of the antimony. For in this process the acid of the sublimate quits the quicksilver, and unites with the regulus part of the antimony, by this means forming the butter; the sulphur of the antimony unites with the quicksilver, and forms a

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cinnabar.

cinnabar. The quantity therefore of cinnabar depends upon the antimony's abounding in sulphur. By this process it appears, how near the sulphureous part of antimony approaches to the nature of common brimstone.

Authors differ greatly in regard to the proportion to be observed between the sublimate and the antimony, some advise equal parts of each, others recommend three times as much of sublimate as of antimony. If the sublimate be used in too great a proportion, pure quicksilver will be found after the operation. If the antimony exceed, some antimony unaltered will be left. I have generally found, that with twice as much sublimate as antimony the process succeeds most completely. This process so far as relates to the cinnabar being thus precarious, what has been usually found in the shops under the name of cinnabar of antimony, is only a little antimony mixt with the ingredients for common cinnabar, before sublimation.

The butter of antimony, by repeated rectifications, or being left open to the air, runs into a liquor, and is then called oil of antimony. This is used as a caustic, and is esteemed for keeping itself confined to the place, on which
it

it is layed, without spreading, as other caustics do.

Butter of antimony being put into a large quantity of water, the antimonial regulus precipitates from it in the form of a white powder, called *mercurius vitæ*. This is a very strong emetic; but has nothing of quicksilver in it, as its name would imply, but is the regulus of antimony washed from part of the adhering acid.

Antimony in powder well mixed with thrice its weight of nitre, and thrown by degrees into a crucible moderately heated, and then removed from the fire and washed in water, produces what is called diaphoretic antimony.

If upon butter of antimony be poured spirit of nitre, till all ebullition ceases, and then the fluid part of the mixture be drawn off, a powder will be left void of any emetic quality. This is called bezoar mineral, and has been held in high esteem by many, and put in the first class of the medicines dignified by the name of alexipharmacs. But as it resembles very much diaphoretic antimony, so it has no greater qualities. If it be melted with tartar, charcoal, or the like inflammable substance, it returns to regulus of antimony, as diaphoretic antimony does.

The

The liquor drawn off is called spiritus nitri bezoardicus, and will dissolve gold, like aqua regia.

From all this we see beyond dispute, that the spirit of sea salt is an ingredient in butter of antimony; because from the butter of antimony the spirit of nitre acquires a power of dissolving gold; and of the ingredients used in that preparation, common salt is the only one, from whence the spirit of nitre can receive this power.

The acid spirit of sea salt contained in sal ammoniac will also act on the metals.

If this salt be mixed with an equal weight of filings of iron, and being well ground together they are put into a retort, with a fire raised by degrees to a due height, a sublimation will fix itself in the neck of the retort tinged by the iron. This mixt with the bottom and sublimed again will be more deeply coloured than before. Also if to what then remains more sal ammoniac be added, a like sublimation may again be made. And by the repetition of the process all the iron may be sublimed.

In the same manner sal ammoniac mixt with the colcothar of any of the vitriols, will carry up with itself their metallic part. Hence shoots martialis ammoniac.

If

If quicksilver, tin, sal ammoniac, and flowers of sulphur are mixt together in just quantities, and put into a bolt-head, heat being gradually applied at length a separation will be made, and a light brittle substance of a golden colour found in the middle which is called aurum musivum. The form of the process is this, first, to melt the tin, and then add the quicksilver to it, which readily mixes with the tin, and, when cold, composes with it a brittle body; and this, when powdered, is to be well rubbed with the other ingredients: when the sublimation is completed, there comes out of the bolt-head a fetid smell resembling that of rotten eggs.

Though the acid spirit extracted from vitriol will not operate on all the metals: yet the same acid in sulphur will act upon every one, upon all but gold and tin alone, and upon them, if it be first melted with a lixivial salt.

In order to calcine the metals with sulphur it is usual to reduce them to small parts, that they may the sooner be penetrated by the sulphur. This may be done either by granulating the metal, or by stratifying thin plates of it with the brimstone. This method of stratification, as the chemists call it, is usually described thus; that the bottom of a crucible be first covered
with

with sulphur; then a plate of metal laid upon it; and this being also covered with sulphur, another plate of metal laid on, thus proceeding till all the plates are put into the crucible, the uppermost plate being also covered with sulphur. But the same intention may be more compendiously answered by thrusting bits of the metalline plates perpendicularly into the sulphur, after that has been put into the crucible.

An expeditious method of granulating the metals is by pouring them, when melted, into water from some height. If the metal is not a valuable one, it is usual to pour it through a birch broom.

Tin is often reduced to powder by pouring it melted into a box, and at the instant it begins to set shaking it about. The like may be done, though not quite so easily with other metals: for the metals in the point of their change from a fluid state to their solid and malleable consistence are brittle.

If quicksilver be stirred into melted brimstone, it will incorporate with it, and upon their union the mixture usually takes fire. It is immediately extinguished by putting a close cover upon the vessel, in which the matter is contained. This mixture sublimed is called factitious cinnabar from its near resemblance to the native,

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tive, which is a natural union of sulphur and quicksilver. The painters use this preparation under the name of vermillion.

If a bar of iron be heated glowing hot, it melts down at once into a brittle calx upon the contact only of a roll of brimstone.

This calx dropping into water, freed from the brimstone and reduced into a very fine powder is called chalybs cum sulphure preparatus.

LECTURE XIX.

HAVING inquired into the principles of which metals consist, we shall now consider, in what form they are found in the earth, and by what arts they are extracted from their respective ores.

Metals are sometimes found pure, sometimes mixt with and concealed in other substances.

All the gold, we have, is found in the visible form of gold. Some is found in small grains, and dust among the sands of certain rivers, from whence it is separated only by agitating the sand in water, whereby the gold, having a much greater specific gravity than the sand, subsides, and collects together at the bottom of the vessel, in which the operation is performed. Thus is collected all the gold we have from Africa : and here it is separated from the small remains of sand still concealed in it by melting it with nitre. The nitre converts the sand into a glass, which rises out of the metal upon its melting, and swims upon it in a separate body.

In America the gold is found in veins within a white rocky spar : from whence it is extracted
only

only by grinding with quicksilver. Quicksilver, as I shall shew hereafter, will unite with, and, as it were, dissolve gold : and therefore in grinding the golden spar with it, the gold is imbibed and separated clean from the spar.

In the ores, where silver is the predominant metal, it also is usually seen in them in its metallic form. And in America is separated by quicksilver, as gold is, only with some larger apparatus, and some additional operations to prevent other substances, often found in the ore, from obstructing the quicksilver in its imbibing the metal.

Gold is said to be contained in some substances, where it is not seen, in its metallic form ; as in particular in sea-sand, and in some flints ; but not in quantity sufficient to make the extraction of it profitable, except where it is found in ores of other metals.

A great deal of silver is extracted from ores, where it does not appear visibly. A great many lead ores contain a portion of silver. Most of those called silver mines in Europe are mines of lead enriched with silver.

The other four metals, copper, lead, tin, and iron are seldom met with in their metallic form. Copper is, I think, the only one ever so found.

These

These metals are generally in their ores corroded by an acid spirit, which must be separated from them in order to obtain the metal pure.

This acid spirit is of the vitriolic kind, as that is the acid, which is found in brimstone, wherewith we have already observed, that marcasites abound. And marcasites generally accompany metallic ores; and are themselves scarce ever free from some metal.

Besides this acid spirit there is also found in many of the ores themselves the usual contents of the pyrites, sulphur, and, not unfrequently, arsenic; insomuch, that in calcining ores these substances visibly exhale from them.

Thus ores are compounded of these several parts. The metal either in its complete form, or eroded by an acid; stony and earthy parts; besides the contents of the pyrites sulphur and arsenic. These last, if left in the ore, when it is melted, will corrode the metal, and prevent its receiving the due metallic form. But as these substances are both volatile, they may be exhaled from the ore by a proper degree of heat, before it is melted.

Now as metals are compounded of two substances, one, which constitutes the bulk of the metal, and another, whence it receives its metallic

tallic form, the art of smelting consists of these two particulars; in the first place to free the ore from the acid, which has corroded the metal, and from all other substances that may do so in the melting; in the second place to provide, that the metal be furnished with a due portion of the substance necessary to maintain its metallic form. This we have shewn to be a substance common to metals with other bodies, being that, to which inflammable bodies owe their power of burning.

The greatest part of copper ores contain so much of this inflammable substance; that the art of extracting copper from its ore, called by the workmen smelting, consists in freeing the ore from its acid spirit.

They commonly first burn away the grossest part of the sulphur, which lyes mixt in the ore, in a furnace not capable of giving a degree of heat sufficient to melt the ore; and after this light roasting is performed, they remove the ore into another furnace of the same kind; but so built as to give a greater heat; and in this furnace the ore is melted. These furnaces are one of the two kinds of reverberatory furnaces, I described at the beginning of these lectures. One is that wherein we lately distilled some of the acid spirits, where the vessel containing the

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sub-

subject to be distilled was so suspended within the furnace over the fire, that it hung in the middle of the flame. But to these now mentioned the name of reverberatory still more properly belongs; for in these furnaces the fire being made on one side the bed, which holds the ore, and the exit for the flame and smoke on the opposite side, the flame is brought over and beat down upon the ore. The roof of the furnace descends in passing from the fire-place to the exit for the smoke; for the flame of the fire diminishes, as its distance from the fire increases; and by this structure of the furnace the space between the surface of the ore, and the roof of the furnace being also diminished, the flame, when less in quantity, is condensed, so as to give the same degree of heat. By this means the whole ore is equally heated.

(Here the model of the copper furnace.)

It is so difficult to disengage copper from its ore, that in most ores there separates from the slag upon the melting only a blackish brittle substance impregnated with copper. This the workmen call a regulus of copper. From this by a second roasting long continued and subsequent melting, both performed in the latter furnace, copper will separate.

Some

Some rich ores yield copper upon the first melting. It is found advantageous to work richer and poorer ones mixt together: for the rich ores are sometimes defective in the inflammable part, and the poor ores abound with it.

When real copper is thus separated from the ore; there yet requires farther roasting and other management to render it pure: many ores abound with iron; in these the copper is rendered coarse and brittle by a mixture of this metal with it; which must by subsequent calcinations and meltings be roasted out. If in these operations the copper is deprived of its proper portion of the inflammable substance I observed to be necessary to metals for the support of their metallic form, this is to be restored by adding some inflammable substance, that will not too soon be dissipated, such as tartar, charcoal, and the like. But while the copper is thus restored, the iron will remain burnt, and thereby be separated from the copper.

This method of smelting in the reverberatory furnace is practised only in our island, nor here above three or four score years.

It was first begun upon copper; but soon after the like method was put in practice upon lead ore.

Lead ore contains so much of a sulphureous or inflammable part, that by roasting only a large portion of metal will separate from it.

Lead ore is roasted in the same kind of furnace as copper ore, but, while it is roasting, it becomes soft, and, as it were, half melted. To prevent its softening too fast, they throw lime in upon it, which keeps the ore dry. They stir the ore and lime together with long irons through holes made in the sides of the furnace for that purpose. The metal here melts from the ore during the roasting, and is let out, at certain periods, by a hole made for it in the side of the furnace.

(Here the model of the lead furnace.)

Lead ore does not abound so much with the inflammable substance so often mentioned, as copper ore does: insomuch that a part of the metal is still left in the ore, and wants the addition of such a substance to produce it.

To this end they melt their slags by the blast of bellows upon a hearth mixt with fossil coals already so far burnt, as to have their humid part evaporated, and past sending out a gross smoke. Such coals are called coakt coals. Coals thus treated are in respect to crude coals, what charcoal is to unburnt wood.

These

These slags would melt as thin in the furnace as here. But here they receive from the coals, while they melt, an inflammable part necessary to their supplying more metal. After all, when the slag has laid a time exposed to the air, it will yield more lead by being melted upon this hearth.

(Here the model of the slag-hearth.)

In some countries of England the first part of the lead is still melted from its ore with billets of wood. This is done in a square furnace, into which the wood is first thrown in sufficient quantity to make the proper fire, which is blown up with bellows moved by a water-wheel; and upon this is thrown the ore, from which in melting the lead runs out: when that ceases, the slag is raked out, and another fire made up with fresh ore. From these slags is extracted the remaining lead in a slag-hearth with the pit-coal of the country. On Mendip hills, they use no pit-coal, but wood, and charcoal.

(Here the Derbyshire and Mendip-hills furnaces.)

The ores of tin and iron are defective in the inflammable part. The metals therefore are not to be separated from these, without adding some material from whence this inflammable part may be communicated. Tin ores are now melted in Cornwall in reverbera-

tory furnaces, as copper and lead ores ; but not roasted in them. They are spread over with small coals, and melted directly.

Thus we now smelt in England copper, lead, and tin, by the help of fossil coals. In all other countries metals are smelted with charcoal. The scarcity of charcoal, and great plenty of fossil coals with us, gave occasion to our proceeding in a different method. We made no copper in England, till the present way of working was invented. Lead and tin we have wrought upon time out of mind. Our island has been the principal source of tin from the earliest accounts of time, and continues still to be so for both metals.

Scarce any successful method has yet been found of communicating to iron ore the inflammable part from fossil coals.

With charcoal the method of smelting metals is this They first lightly roast the ore to expel the loose sulphur, laying the ore upon wood or small charcoal set on fire. Then they pound the ore, and put it into the smelting-furnace mixt with charcoal. This furnace is only a building of brick, open at top, where the ore and charcoal is thrown in with baskets alternately, and having a small hole on one side at the bottom, before which a basin is made to receive the metal,

tal, as in melting it flows out from this hole. This furnace Agricola describes with a cavity equally wide from the bottom to the top. But at present in our iron furnaces, and in the other furnaces abroad also, its cavity is made widest in the middle, narrowing both upwards and downwards. Toward the bottom of the furnace the noses of two pair of bellows enter, which blow alternately and are moved by a water-wheel. By this vehement blast, and the great strength of the charcoal fire, the acid spirit is expelled from the ore, and the fuel at the same time supplies the metal with a due quantity of the inflammable substance necessary to it. In iron lime is always added to imbibe the acid spirit of the ore, and thereby assist the fire in separating it from the metal.

Iron ore before it is thrown into the furnace undergoes a slight degree of roasting by being piled up with small charcoal, which being set on fire by its heating the ore renders it brittle, whereby it is more easily broken into small fragments.

(Here the model of the iron furnace.)

Iron thus melted from the ore is not malleable, but requires farther management to give it that property. This is effected in the following manner. They heat it with charcoal in a

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forge,

forge, where at first it melts, but at length by imbibing from the coals a larger portion of their inflammable part, and the separation of a quantity of a glassy drops (called by the workmen cinder) it grows gradually tougher, and acquires the soft, but tenacious consistence, which malleable iron has, when strongly heated. If it be not brought to a malleable condition by one melting, it is heated over again in like manner; but the first heating is sufficient for the greatest part of the iron, which is wrought upon to be rendered malleable.

As the iron comes thus hot out of the fire; after having first received a few blows with wooden mauls or hand-sledges, it is carried, and held under the blows of a large hammer, that is raised up by a water-wheel. This hammer beats the small remains of slag or cinder out of the metal, and unites it into a close body of malleable iron. Afterwards this iron by repeated heatings and hammerings is beat out into bars of different sizes, and fitted for the market. But none of the subsequent heatings are so great as the first. In forming the bars they beat out the middle part first; then heat it at a lesser forge, and beat out the ends.

(Here the forge-hammer.)

Iron

Iron is less fusible than its cinder or slag; which is the reason of using the hammer to beat the last remains of the slag out of it. This is an operation peculiar to iron; for all other metals, by their fusibility, run liquid from their slag. But as iron is less fusible than its slag; so the slag of iron is not so fusible as to flow perfectly from the iron without the assistance of the hammer to force it out. All slag flows more or less tenacious after the manner of glass.

In iron ores, that are very rich in metal, good part of the iron may be obtained from them, with a much less fire than what is required to melt the other ores.

These ores may be originally wrought at a forge, and the iron rendered malleable at one operation. These forges have a pit, which being filled with coals, and ore laid upon them; as the ore softens it sinks down into the pit, and the slag runs from it, as in the other case of fusible iron. The iron thus purged is taken from the pit, and hammered clean from the remaining slag, as in the other case.

But here also must be put into the fire along with the ore a quantity of lime; that the lime, by dissolving the sulphureous part of the ore, may facilitate the separation of the slag. However

ever these forges seldom or never extract the whole quantity of the iron from the ore.

In smelting silver or gold ores, where these metals are got by melting the ore, they put a quantity of lead in the bason, which receives the metal. This lead keeps melted by the heat of the furnace, and imbibes the silver and gold from the slag. The metal is afterwards separated from the lead in the manner described, when I shewed the method of refining these metals by the help of lead.

Our refiners have an operation something similar to this, which they call melting their sweep. In parting silver from gold by aqua fortis, it is no uncommon accident, by the breaking of their glasses, to have their metal mixt with sand. Such sand, together with any dirt, wherewith they suspect metal may be mixt, they at certain times operate upon to recover the metal. It is performed in a furnace, like that, wherein silver is smelted from its ore by charcoal. Into this furnace is thrown the sweep, and litharge mixt together. In the charcoal fire the litharge is reduced, and runs out in the form of lead, having imbibed, and bringing with it what silver or gold was mixt in the sweep. To effect more perfectly the separation of their metal from

the sand and dirt of the sweep, they likewise from time to time throw in the slag or cinder of iron. This melts the sand, and separates it more effectually from the metal. And congealing as soon as soon as it comes out into the air; by a large poker they keep this glassy and tough slag up in the mouth of the furnace, and thereby regulate the running of the metal at pleasure. The cinder of iron is better for this use than the slag of any other metal; because it is of a more pure glassy substance than the rest.

There is also another method, which was mentioned above, of separating these metals from their ore, which in ores, where the metal exists in its metallic form, makes the most perfect separation. After the ore has been freed by calcining from its loose sulphur, when that is necessary, it is well mixt with quicksilver by grinding them together. The quicksilver unites itself with the silver and gold, and by that means separates them from the ore. The quicksilver is separated again from the ore, partly by straining through leather, and partly by distillation. Before quicksilver is mixt with the ore, it is necessary to free the ore from its loose sulphur, if the ore abound therewith: otherwise
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the quicksilver will lay hold upon this sulphur, and not act upon the metal.

Copper is so stubborn a metal to free from its ore, that once smelting even with charcoal will not often do it; but only produce a brittle regulus, which must undergo subsequent roastings, and then be melted down again before pure copper can be obtained from it.

What has been said may suffice to give a general idea, how metals are extracted from their ores. But I intend to explain more particularly the method of examining ores in small quantities, whereby the goodness of any parcel may be judged of. This art of assaying admits of several compendiums not to be put in practice with profit in the great works; the account of which, and illustration by experiment, I design for our next meeting. I shall here only in general observe, that as ores come out of the mines mixt with earthy and stony substances; all such heterogeneous mixtures, which are light enough to be washed off are separated from the ores by that means, before they are carried to the smelting-houses: and therefore it is after this washing, that they are usually assayed. But iron ores are in this to be excepted: they do not

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in general require washing; for they lie in the earth in a different manner from all others. The rest of every kind run in veins through the rock, which contains them; but iron ores compose the intire body of the rock or hill.

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LECTURE XX.

WHEN the smelter purchases ores from the mines, it is necessary for ascertaining their value to examine by assaying a small quantity, what portion of metal the ores contain.

Though this assay may be made by the same means, as the separation is performed in the great works, yet certain compendiums and assistances are here usually made use of by additional materials, which cannot in the larger operations be admitted with profit. These additions are usually called fluxes : and are of different kinds.

As ores in assays, as well as in the great works, are divided by smelting into two parts, the metal itself, and a dross or slag of a glassy consistence swimming upon it, while they are both fluid ; some fluxes have no other use than to assist in rendering this melted slag more liquid, that a less degree, or shorter continuance of the fire may melt it thin enough for the metal to fall freely through it. These fluxes are the three salts, borax, nitre, and the alkaline salt of vegetables ;

vegetables; for any of these will melt with stony substances into glass. Glass is also an expedient sometimes made use of in very stubborn slags; but it ought to be of the most fluxile kind, except flint-glass. That must not be used, lest the lead in its composition should be reduced in the operation, and by joining with the metal of the ore falsify the essay.

These fluxes are always useful, whenever there is danger, that the metal, after it is separated, may be burnt, and thereby diminished, by the strength or continuance of the fire required to liquify the slag; but they are most necessary, when the fire is weak.

Another sort of fluxes regard the metal itself; which are either such as will furnish a due portion of the requisite sulphur, when that is wanting; or such, as may absorb whatever substances in the ore might corrode and destroy the metal.

The fluxes in common use are often compound in their effects, partly supplying one office, and partly another. Of this kind is that called the black flux. We have seen tartar and nitre mixt in equal quantities burn together into a simple alkaline salt. But if the tartar be taken double to the nitre, and the mixture be set on fire, while one half of the tartar is reduced with
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the nitre into an alkaline salt, the rest is only burnt to a black coal. This composes the black flux; and when mixt with any ore in melting, the coal is fitted to supply the requisite inflammable part to the metal, while the salt attenuates the slag. This flux is apt to cause a great intumescence, and endanger the carrying over some part of the ore out of the melting pot. But this inconvenience is remedied by covering the whole mixture with common salt, which dissolves the tenacity of the surface, and prevents the intumescence.

In lead ores iron is the most commodious flux; for this metal will strongly unite with sulphur and even arsenic, thereby imbibing all such substances in the ore, as might destroy the lead; and at the same time will supply the lead with what inflammable part it may want, itself abounding therewith, as we have seen by its burning and flaming with nitre.

But this flux cannot be used in any other ore, because it will join itself with the metal of the ore; but with lead it will not join.

Tin ore may be melted with a simple flux, this ore requiring no absorbent; but only a little charcoal, or some such inflammable substance to give the metal its form; though as it is a metal the soonest burnt of any, and its ore
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has a slag not very easy to melt, some salt to facilitate the flowing of the slag will be a very useful addition. This may be borax. But before melting it is usual to wash away as much as possible of the stony and other terrestrious substances, with which the ore is mixt, all such substances being lighter than the grains of ore, wherein the metal is contained; and if the ore is mixt with mundics, it is expedient before washing to roast out the volatile part of those substances.

Iron ore requires charcoal to give the metal its form, and some alkaline material to absorb the acid spirit; for which purpose lime is the most effectual; so that lime with a third or fourth part of charcoal makes the best flux for this ore, with which it may be melted, after it has first been made red hot by itself, that in smelting it may not upon the first heat fly out of the melting pot. Here the chief difficulty is to make the fire strong enough. The cinders of coals, if not too much burnt, perform this essay best.

Copper ore is the most difficult to smelt of any. It joins so freely with all other metals, and is so readily corroded both by acids and alkalis, that there is no commodious material known for imbibing either the sulphur contain-

ed in the ore or the acid spirit, with which the metal is joined. They are both to be expelled by roasting. For this reason copper ore is sometimes essayed without any addition, except perhaps some salt in the melting to promote the fluxility of the slag; but is roasted or calcined, and then melted down, as in the larger work. Here one roasting and melting will not bring copper out of most ores. But if the work has been carried on well, the copper will appear at the second melting. To facilitate the roasting, the ore is to be beaten to a gross powder, and be kept stirring all the time it is in the fire, that it may not clod together, as it will do, were it left to itself. If it happen to clod much, it should be removed from the fire, and powdered again; for it roasts, while in lumps, but very slowly. The chief art in this operation is to judge, when the ore is so far prepared, that metal may be expected from it: for the roasting may be continued, till the metal shall be calcined, and burnt up to dross. When this has happened, it may be known by the colour of the slag, which then appears tinged with the metal. The remedy in this case is to melt the slag down again with some material proper for restoring the inflammable part, which has been burnt out. For this purpose either
charcoal

charcoal or tartar may be used: tartar will the least thicken the slag.

When the ore first grows hot, it feels sluggish and heavy, like flower, under the rod, where-with it is stirred. By degrees it grows lighter and feels dry like sand. By this change the roasting is to be judged of. It is complete, when all the sluggishness upon stirring is gone. At this time also it loses its red colour upon the surface, as soon as the stirring is intermitted, whereas before the redness continues some time upon it.

But copper ore may be more expeditiously essayed by roasting, till it has lost all smell, and then melted with borax or some such salt to promote the fluidity of the slag, and also a little charcoal or tartar burnt black, lest the metal should have been in any measure calcined. Though care should always be taken not to roast the ore more than necessary; for metals calcined never are restored again in full quantity.

In authors is found a much greater composition of fluxes, than I have recommended. But I apprehend the weakness of their fires rendered such great apparatus necessary, and these copious fluxes are attended with an inconvenience: by their bulk they so fill the melting pot, that

but a very small portion of the ore can be taken for the essay.

In relation to silver and gold ores, they are usually essayed by putting them to lead in fusion; whereby, while one part of the lead calcines and unites with the stony part of the ore, the rest imbibes the metal, from whence it is afterwards to be separated. If the ores are stubborn in melting, litharge should be added to them, or even the glass of lead before mentioned. If the ores contain sulphureous or arsenical ingredients, those are previously to be roasted out.

In assaying these ores the lead, into which the ore is put, (either alone, or with litharge or the glass of lead, if the ore be of difficult fusion) is usually contained in a vessel made in the manner of a test; but, instead of bone ashes, of some earth. The reason of which is, that the lead may not be imbibed, before it has fully liquified the ore. The earth of these vessels ought to be of a kind as little liable to vitrify and be eroded by the lead, as may be; and when the lead is covered over with slag, and that melted so thin, that the metal in the ore may easily fall through it, the vessel is to be removed from the fire, and when cold the slag separated from the lead, which is to be afterwards

wards roasted upon a test of ashes, that the metal of the ore may be received pure. The whole process may be performed upon a test of bone ashes, if the quantity of ore essayed is so small, that as much lead may be used without rendering the operation tedious, as will suffice, before it shall be imbibed by the test, for liquifying duly the ore.

But a more concise method is to melt the ore in a crucible with litharge, or, if it be a stubborn ore and require a long and violent fire to be brought to fusion, with glass of lead; and then by the addition of charcoal to restore the lead, which will carry down with it the metal of the ore. If the ore require a long or violent fire, the glass of lead is to be used, lest litharge should corrode the melting pot.

LECTURE XXI.

HAVING shewn how the true metals are separated from their ores, we shall next consider the imperfect metals, and their ores.

Of the imperfect metals quicksilver differs from those properly called metals by its perpetual fluidity; the rest, which are solid, by the want of malleability, though they have an external appearance and weight resembling that of a true metal, and are fusible in the fire. They differ from glass in not being transparent, and from salts by not dissolving in water. The chief of these, as has already been mentioned, are bismuth, spelter, and the metallic part of antimony.

Quicksilver is frequently found in its metallic form; so that it is separated from the earth containing it, partly by washing it in water only, or at most by heating it. For quicksilver with a degree of heat scarce exceeding that which will melt tin, is rendered volatile; and therefore so much of the quicksilver as does not wash out of the ore, is separated from it by a simple distillation.

Native

Native cinnabar is an ore of quicksilver, from which the metal cannot be obtained without more art. It is a union of quicksilver, and sulphur. And, as we have seen, both lixivial salts and lime act upon and dissolve the sulphur, so either of them mixt with this ore cause the quicksilver to separate from it upon distillation. The filings of iron will produce the same effect.

A moderate degree of heat without any additional art separates bismuth from its ore, which is little else than bismuth already formed, intermixt with earthy parts.

Agricola, who is an author, that always ought to be consulted upon the subject of metals, describes the manner of doing it thus. The ore is laid in a cavity, for the most part made in the earth, sometimes round, sometimes a long trench; and billets of wood being laid over upon the ore, and set on fire. The bismuth soon runs from the ore, and flows out into a receptacle from the cavity, where the ore is contained, through a passage left open for it.

Spelter bears some analogy in its properties to bismuth. It is produced near Goslar in Germany, after this manner. There are lead mines near Goslar, which contain a particular kind of ore. It is a stubborn one, very difficult to melt. From this ore sublimes in the melting a sub-

stance, which is found, after the melting is over, sticking to the inside of the furnace. This substance they shake down into a small fire made at the bottom of the furnace; where it melts. This is spelter. The principal consumption of bismuth is by the pewterers, who make with it a kind of folder.

Spelter is chiefly used for foldering by the copper-smiths, and braziers; and for making a mixt metal much in use; now usually called Bath metal; but formerly prince's metal, the invention of it being ascribed to our prince Rupert.

Spelter is remarkable for wasting in flame, when melted.

Antimony, the third mineral now under consideration, comes to us prepared only by melting down the ore, and casting it into molds; whereby the antimony is separated from the loose earth, wherewith it may be mixt.

But this antimony still resembles more a metalline ore than a metal; by other methods a metallic part is separable from it, as much resembling a metal as bismuth and spelter; but brittle and even less capable of bearing the hammer than spelter.

Antimony consists of two parts. A sulphur not very different from common brimstone, and another part, as has been now said, which may
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be made to appear under a metallic form, except that it is not malleable.

We have seen nitre inflame with sulphur. In the same manner nitre will burn out the sulphur from antimony, and leave the residue a calx, (called diaphoretic antimony described already) which may be brought to a metallic form. For this purpose it is only necessary to melt it with some inflammable substance. The metallic body thus produced is called the regulus of antimony; and being taken into the stomach vomits very strongly.

If only equal quantities of nitre and antimony were mixt, and thrown together into a hot crucible, the result will exhibit a substance strongly emetic, though it will be a little less violent than the forementioned regulus of antimony. This preparation, usually called *hepar antimonii* and *crocus metallorum*, is named in our present pharmacopœia *crocus antimonii*. The practical chemists have gradually reduced the quantity of nitre to half the weight of the antimony, and only set the mixture on fire.

The emetic quality of this medicine will be rendered yet somewhat more moderate by boiling it with an equal weight of the cream of tartar, till they are united. This medicine is called *tartarum emeticum*.

The

The regulus of antimony is not usually prepared in the manner proposed above. The process is shortened thus.

Antimony and tartar and nitre being mixt in due proportion; this mixture by little and little is to be thrown into a hot crucible; and when the whole is put in; it must remain in the fire, till all sparkling ceases, and the matter is well melted; then being poured out into a warm iron mould a little greased, as soon as cold a compact metalline substance will be found at the bottom, which easily separates from what is over it. This is called the regulus of antimony.

The quantity of tartar ought to be equal to twice that of the nitre, and the antimony may be from an equal weight with the tartar to a third part more.

Iron also acts very strongly on sulphur, and there is another method of separating this regulus, by the use of that metal.

Take any quantity of antimony and about half as much iron. Let the iron be heated in a crucible till it becomes red hot; then let the antimony be thrown in upon it. When the antimony begins to flow, let nitre be thrown upon it by degrees, till the quantity thrown in equals near a quarter part of the antimony. After this
let

let the matter flow with a strong heat : then the iron, being corroded by the sulphur of the antimony, flows along with the rest of the materials into one uniform fluid mass. When the matter flows like water, let it be poured out as before ; and a large quantity of regulus will be found at the bottom. Melt this regulus again and throw in upon it a fourth part as much fresh antimony, as was first used ; and, when this also melts, add as much nitre as before ; and, when the matter flows with a strong heat, let it again be poured out, and a regulus will be found at the bottom with fresh dross or scoriæ at top.

Let this regulus be melted again with the same quantity of nitre alone, and fresh scoriæ will separate from it.

Let the regulus now produced be melted again with the same quantity of nitre, and more scoriæ will separate. In these two operations, especially in this last, the matter must flow with a very strong heat. But, if the heat be very intense, it must not be too long continued, lest the antimony corrode the crucible, and be lost. If the heat is more moderate, a longer continuance of it will be necessary. If the processes have been well performed, there appears now upon the regulus a kind of star.

The

The regulus of antimony, as I observed above, is an exceeding strong vomit; and has this remarkable property, that infused in a liquor it communicates its emetic quality in proportion to the quantity of the liquor, and not in proportion to the quantity of the regulus infused. This however is no more than, that the liquor will imbibe only a certain quantity from the regulus; and when saturated will receive no more. What the regulus parts with is very minute in quantity, and not to be discerned under a long time.

Of this regulus cups have been made, in which liquor being poured would in a night's time acquire an emetic quality. The regulus, that has impregnated wine with an emetic quality, will still impregnate more wine with the same quality.

If we consider, how vast a quantity of liquor will receive the emetic quality from a small portion of the regulus, it will appear to be a dangerous medicine to be given in substance, for the vomiting will cease only by the medicine's being totally returned out of the body.

The scorix separated from the antimony in preparing the regulus have also an emetic quality, and will run, being exposed to a moist air, into an emetic liquor; especially the scorix in
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the latter way of making the regulus. This liquor is called the golden oil of antimony from its colour. These scoriæ receive their emetic quality from some portion of regulus contained in them; for, if they are melted again with a little tartar or charcoal dust, more regulus will subside from them.

Antimony is one of the best materials for the perfect purification of gold; for if this mineral and impure gold be melted together, the sulphur of the antimony will unite with and retain every other metal, with which the gold may be mixt, while the gold subsides, accompanied with so much of the reguline part of the antimony, as its sulphur has quitted; and this regulus in a strong fire will fume away, leaving the gold pure.

To the present class of substances arsenic is most properly to be referred. It resembles antimony in an emetic quality, but is so violent as to be an almost inevitable poison to every creature, that shall have taken it into the stomach. Calcined with nitre it loses its activity altogether, and becomes a harmless calx; melted with iron it yields a metallic part, from its resemblance to that part of antimony, usually called the regulus of arsenic.

Arsenic is contained more or less in most mundics; but is usually extracted from a particular kind called cobalt. Cobalt calcined and mixed with sand is used by the potters under the name of zaphor, being their blue. Zaphor melted with an alkaline salt is smalt. In the calcination arsenic rises in smoke, and is collected in a long and winding chimney, where it settles in the form of a white flower.

Some cobalts are unfit for making smalt or zaphor. But from these also arsenic is sublimed. As arsenic in its first sublimation rises in form of flowers, it is sublimed over again from iron pots into an earthen cover of a cylindrical shape, where it unites into a cake in the form in which it is imported hither.

This arsenic is white. There are two compositions made from this; one called yellow the other red arsenic. The yellow is produced by subliming white arsenic with a twentieth part of brimstone, red arsenic is the result of the like process with twice the quantity of brimstone, and a farther addition of a particular kind of cobalt, called in the German language kupfer nikel.

Black

Black lead, wherewith pencils are made, a mineral, almost peculiar to our country, bears also some resemblance to antimony. The people of the country, where it is dug up, infuse it in beer or wine for an emetic. But this substance is neither volatile, nor will melt with any degree of heat.

LECTURE XXII.

WHEN gold or silver is melted with a strong heat; if they have any mixture of another metal, that other metal will be seen to burn upon its surface. Now it is to be observed of metals and their calxes, that melted metals mix with each other, but not with other substances. For instance, if sand, earth or stones be put into melted lead, they do not at all incorporate with it; but when the calx of lead or of any other metal is melted, it then unites freely with these earthy substances, but not with any metal, not even with its own. Iron indeed being in some measure of an earthy substance joins more with such substances than other metals: this is the reason, that melted glass will stick to this metal, though to no other.

Thus, when unfine gold or silver is melted, the metal mixt with them, as fast as it burns to dross, separates from them. However lead vitrifying much more easily than any other metal, if this is mixt with the unfine silver or gold in a large proportion; while it burns from them, it carries

carries away all other base metals much more effectually than otherwise could well be done.

But the first thing necessary, in burning lead into litharge, is to provide a proper vessel to contain it. The only materials, fit for this purpose, are some kind of ashes free from any salts, such as the ashes of burnt bones, or of vegetables, after their salts have been perfectly extracted. The ashes of burnt bones are mostly used. If the vessel, wherein the lead is put, were made of any other materials, they being more easily vitrifiable, would be melted down by the lead, and let out the metal.

The refiners prepare a vessel with these ashes after this manner : they ram them hard into an oval iron ring, and by scraping out a cavity form a kind of shallow dish. This they call a test, it is also called a cupel. This test they place under a chimney, where a large double pair of bellows are fitted so, as to blow close over it. Into the cavity of this test they put their metal together with a little charcoal to begin the fire : over all they lay large billets of oak ; which, taking fire, burn all the time of the operation. They prefer oak to other wood, because it will burn longer, before it is consumed. When the metal is upon the point of melting, they put in lead upon the metal. Upon the approach of

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the lead, both metals soon melt down together, and by the intenseness of the heat the lead burns up to litharge. In a smaller heat lead would have a dross gather in a skin upon the top of it; but in this great heat the dross melts, and flows like drops of oil upon the metal. This is litharge. On the side of the dish opposite to the bellows is a hole pierced through, at which the litharge may pass out, and as soon as the workman perceives litharge to rise, he scrapes away a shallow channel in the test leading to this hole. The litharge, blown toward this channel by the bellows, passes off, and drops under the test. And this litharge carries away with it all base metal, wherewith the silver or gold may have been mixt.

Silver and gold are refined in essays after the same manner. Here it is usual to put the silver or gold to be tried upon a small test made with the ashes of bones or horns, and place it either so, that the flame of a wind-furnace may draw over it, and consume the lead melted with it, or else to place the test under a vessel, we formerly described, called a muffle, and heap charcoal over it in a furnace usually made of iron, and called from this office of it an essay-furnace. This furnace we have before described, and now we shall see the manner of using it.

In

In this operation the litharge soaks into the test.

Tests are made of bone-ashes in the greater works, because they are a material, which will contain the lead long enough without vitrifying. But these ashes are adapted for essays upon another account also. They adhere together but loosely ; by which means the vessel is a porous body, fitted to imbibe the litharge, as it is formed. Some compose essay-tests of wood-ashes carefully washed from their alkaline salt, only covering the cavity with bone-ashes, and these tests are more porous than the other, whereby they shorten the operation ; but these dry less perfectly than those of bone-ashes, and therefore require much longer annealing, before the lead is put into them. Though these vessels of whatever material they are made, should be well heated before the operation : for as long as any moisture remains in them, they will throw up particles of lead, which often fall out of the vessel, and by carrying a proportional part of the silver with them falsify the essay.

In these essays it is necessary to make use of a quantity of lead, amounting at least to eight times the weight of the metal to be refined, if it contain about a twelfth part of base metal : and

if it be coarser, a greater quantity of lead must be added.

If gold and silver are mixt together, after they are purified by lead from all other mixture, the essay is finished with aqua fortis, as we shall shew hereafter.

I have already hinted, that the use of lead in refining silver and gold arises from its easy vitrification, whereas the other metals, if alone, vitrify with difficulty ; but when mixt with a large portion of lead, they are divided into so minute parts, that the fire operates more strongly upon them. By this means copper, the metal most usually mixt with silver, will vitrify, and pass away with the litharge, whether the litharge be blown off, as in the greater operations, or it be soakt up by the test, as in essays.

Iron will not mix with lead, and therefore is quickly separated, lying upon the top of the lead, and there wasting.

Tin is most difficult to free from silver, and more so from gold. This arises from its resistance to vitrification. I have taken notice, that the burning-glass, which vitrified gold, would not produce that effect perfectly upon tin. For this reason the tin rises presently upon the lead in the form of dross, and there will lie without
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burning away. And in this condition is not so perfectly calcined, but that it holds yet a portion of the silver or gold adhering to it.

The most effectual method of performing this separation is to mix the mass with twice as much copper, as there may be of tin in the composition, and when the tin rises upon the lead to take it off, and mixing it with glass of lead to proceed with it, as in assaying an ore.

The greatest part of lead ores contain a portion of silver. This melts out from the ore with the lead; and is often in so large a quantity, as to be extracted to profit. In this country, where fossil coals are used in the lead works, the operation is performed in this manner. A test of the same form, and made of the same materials, as that employed by the refiners of silver, but much larger, is placed in a furnace, where the flame of the fire draws over it, by the heat whereof the lead is burnt into litharge, which is drove to one end of the test by the blast of large double bellows, that blow constantly over the surface of the lead; and here the litharge falls out of the test by a hole cut through it for that purpose, as in the refining of silver before described. And as the lead wastes, whereby it would fall too much below this hole for the litharge to pass into it, they supply the lead from time to

time most usually by thrusting in the end of a bar of lead, which melting, as it comes over the lead, supplies, the waste of it.

There not being a demand for all the litharge made, the greatest part of it is reduced into lead again by this means. The litharge is put into a reverberatory furnace, like that, we shall hereafter describe, wherein the ores of lead, and other metals are smelted, and being spread abroad is covered with small coals. Then it is heated for some time; after this it is stirred up, and more coals being thrown on, is heated for some time longer; by this means all the litharge will have changed its form, and lead be found in the furnace in its stead. Where ores are smelted with charcoal, they reduce litharge by throwing it into a melting-furnace mixt with charcoal as in smelting ores. The charcoal reduces it. In these places the lead is burnt into litharge by putting the lead into a shallow bed made of bone-ashes laid over a large hearth built of brick or stone. To the bed an iron cover is fitted, and they melt, and burn the lead by wooden billets, which are thrust in over the lead, and the blast of the same bellows both maintains the fire, and directs the litharge to its exit.

If silver be mixt with a large quantity of copper, which often happens in the mines of Germany, where many ores are found containing both metals; there is a method of separating them without destroying either metal. This is by melting down the composition with a quantity of lead, and then exposing the mixture to such a heat, as shall melt down the lead without melting the copper. By this means the lead will run from the copper, and carry the silver out along with it.

This is performed in a furnace of a particular make. This furnace is a long concave floor, with a channel running lengthwise through the middle of it. Cakes of the mixt metal are laid upon this floor, and, as the metal heats, the lead melts down into the channel underneath, and thence runs out into a basin made to receive it.

LECTURE XXIII.

BEFORE we take leave of the effects of fire upon the metals, and metallic bodies, it will not be improper to follow them into the shops of artificers, and make a few remarks upon some of the operations, which they there undergo. But we must first take into consideration two eminent changes wrought on two of the metals, before they come into the artificer's hands : I mean the converting copper into brass, and iron into steel.

Copper is made brass with a mineral called calamy or lapis calaminaris. This mineral is first calcined, that is, heated red-hot in the fire, but no more. Then it is powdered, and mixed with twice its measure of charcoal-dust. In this mixture is set edge-wise pieces of copper-plates to the amount of two-thirds of the weight of the calamy. This mixture is heated together for some time ; at length the heat is made so strong as to melt the copper. As soon as that is done, it becomes brass, and is increased in weight. One hundred pounds of copper produces one hundred and forty pounds of brass. If the
copper

copper be more minutely divided, it will imbibe more of the calamy, and acquire a farther increase in weight. For this reason some granulate their copper, by pouring it melted into water. The brass is cast out into sheets between stones. The only stones once used here for these moulds were brought from France, being dug from a quarry near St. Malo's. But since stones found in Cornwall have come into use for this purpose. The stones are first spread over with loam and horse-dung, and kept by iron bars at the proper distance to make the mould.

The reason assigned for the necessity of casting sheet-brass in these particular kinds of stones only, is, both that the loam adheres to them better, than it would to many other stones; and they are also thought to be capable of giving some vent to the fume, which rises from melted brass.

Brass, if made of good copper, is very malleable; but when made of coarse copper, will scarce endure the hammer.

In the making of brass, if there be added to the other ingredients a quantity of old brass kettles, that have been long in use, and often heated, the metal will be firmer. Without this
addi-

addition the brass cannot be made tough enough to draw out into fine wire.

The best copper for making brass is that, which has been refined something farther than would render it most malleable; when the copper in the phrase of workmen is a little dry. Brass, by being kept a length of time red-hot, will return to copper again.

The operation upon iron, whereby it is converted into steel, is a more useful invention than this of making brass. This is variously described. Agricola says, it is done by soaking wrought bars of iron for some time in fusible iron melted with the addition of a flux, that melts it more freely, and then immediately plunging them in water. In this last part of the operation, I suspect, he confounds the making of steel with the method of hardening it. Steel is not distinguished from iron by its being hard, but by its disposition to be hardened upon being quenched in water, when red-hot, which is not the quality of iron. Some writers say, steel is prepared with the assistance of the hoofs and horns of animals. There is a method in use analagous to this of giving the hardness of steel to the outside of iron by covering it over with the shavings of horns or hoofs and quenching it, when

when hot, in water. After this operation a file will not touch the outer surface of the iron, though the iron within remain soft. In the method practised in England for making steel, nothing is added to the iron but powdered charcoal.

Iron bars are put into pots made in the form of an oblong square. The bottom of the pot is first covered with charcoal-duft, then the bars are laid in rows at some distance from each other, and being covered with charcoal-duft, other bars are laid in this stratification being continued till the pot is sufficiently filled: then the whole mass of bars is covered with charcoal, and sand strewed over all, to prevent the charcoal from taking fire. Each furnace contains three of these pots, the fire being between them, which is raised gradually, and one or more bars are so placed in the pots, that they can conveniently be pulled out from time to time; by which the heat of the fire is judged of; after a due time the fire is let down, and the bars taken out when cold, that they may not be wasted by scales. The bars, when converted into steel, are often found blistered on the outside.

Steel is of a more even texture than iron, and for that reason is preferred in fine works. But the chief property of steel, that distinguishes it from

from iron, is its growing exceeding hard by being quenched in water, when hot, so as to be fit for edge-tools, and be capable of cutting either iron or steel itself not so hardened.

If a piece of steel is made red-hot, and then suddenly quenched in cold water, it becomes hard and brittle like glass. This brittleness is diminished by heating the steel again. But here a small degree of heat only is to be given to the steel, and that different, according to the purposes for which the steel is intended. In order to judge of the degree of heat the steel is now to receive, the workmen rub it bright, and estimate the heat by the colours, which arise upon it. At first it turns a little yellowish, then of a deeper colour, and at length blue. The first colour, before it becomes deep, is the proper colour for gravers, files, drills, masons chissels, razors, lancets, pen-knives, &c. for carpenters tools, that cut wood, the heat may continue till the colour be a little deeper, as also for the tools wherewith screws are made. If it be heated till in the dark it look of a very dull red, and no longer, it is a spring. Farther heated than this, it becomes soft again. In this temper steel is the firmest to resist any force. When harder than this, it is more or less brittle; when softer, it will give way, and bend with less force.

force. For this reason the tools, that carpenters, and others use to turn screws with, are made of steel set to this temper, or rather left in a small degree harder. This spring-temper may be given to steel another way; by putting the steel, after it has been hardened, into oil, and heating the oil over a fire till it flames; then the steel taken out will have acquired a spring-temper. The most common method used by workmen in making a spring, is to heat it a little over a fire, then rub tallow upon it, and hold it again over the fire, till the tallow flames. But this method is not so secure as those, I have now described. Springs have very often a blue colour given them for ornament. This is done after the spring is made, by brightening it, and then heating it, till it acquires this colour. This practice has occasioned Mr. Boyle and others to mistake, and conclude, that the degree of heat, whereby hardened steel is brought to this colour, makes it a spring; but with this heat alone it will be too brittle.

If a spring, after it is made, happens not to stand bent quite according to the design of the workman; by bending it forcibly into the desired form, and in that shape heating it, till it become blue, and keeping it thus till cold, the
spring

spring will retain the shape given it, without losing any of its strength as a spring; it will rather be stiffer. This is an artifice very necessary to the watch-makers. The axes of watch-wheels are made of steel wire set to a spring-temper. They first turn them nearly true, then harden and temper them. But steel in hardening is very apt to crook. When this accident happens in their work, they must proceed, and give the spring its temper, before they can straighten it again. When it is brought to a spring-temper, they strike gently upon the hollow side of it with an edged hammer. The hammer by cutting into the steel stretches out the hollow side, till the work becomes straight. Then they blue it, and when cold turn off the cuts without any fear of it returning to its first shape. But if the steel does not keep perfectly straight, the process repeated a second time is sure to rectify it fully.

When it is necessary for harder steel to retain its figure exactly, they first unite the steel to iron, that no greater part of the instrument be steel, than where the hardness is required. Then, if the steel has any thing altered its figure in hardening, after it is brought to its temper, they can bring it back to its figure by some blows of a common hammer; for the iron will
give

give way, and hinder the steel from springing back again, and the steel how hard soever, will bend without breaking, as much as is ordinarily required in this case.

Steel is more subject to crook thus in hardening, when over-heated. Care should be taken to estimate rightly the degree of heat in giving steel its first hardness upon another account also: for if the heat be too small, the steel will not be hard; if it be too great, the steel will become so brittle as never to recover a proper degree of toughness. It is better to fall short in this heat than exceed; for, if the heat be not strong enough for the steel to be hard, the process may be repeated over again without damage to the steel; but if the steel be over-heated it is spoiled.

Steel should not be forged with quite so great a heat as iron.

Those, who make files, use an artifice, whereby they harden great numbers at once. They have an iron pipe and a rod, that fits it. They wrap up in wet loam a great bundle of files with this pipe in the middle, and by drawing out the rod from time to time, they judge of the heat of the whole bundle. The disposition of the steel to harden by the sudden application of cold to it, when hot, makes a particular management necessary, when it is desired to have cold
steel

steel as soft as possible. For this purpose, when it is heated of a dullish red, they bury it up immediately in hot ashes, and there let it cool. Thus by keeping the hot steel from the contact of the cold air, it will be softer, and cut better either under the file or graver than otherwise. This is called annealing it.

I shall next consider the compositions usually made with metals.

Silver and gold when pure, are so soft, that hardening them in some degree is convenient to fit them better for the uses, to which they are put, either for coin or plate. Silver is thus hardened by a small mixture of copper; gold by copper or silver or by both together. In our mint copper is the metal used. The metal thus added is called the alloy. By standard silver, and gold is meant those metals with that portion of alloy, which is allowed by law.

The standard for our silver coin was most anciently eighteen penny-weights troy of alloy to eleven ounces and two penny-weights of fine silver: and the same standard is in use at this day. This is three parts in forty of the whole in alloy, that is near one thirteenth. Some years past it was enacted, that all wrought plate should be finer, and not have more than half an ounce of alloy in a pound of the whole. This is called
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the new standard. This regulation was conceived to be a means to hinder the silver coin from being melted down by the silver-smiths. But a portion of fine silver mixt with the standard of the coin will readily reduce it to the new standard. And as this small alloy leaves the plate too soft, it has since been made lawful to make plate of either standard.

The ancientest standard for gold was no more than one part in one hundred and ninety-two of the whole in alloy. In the first year of Henry the eighth some species of gold coin had one-twelfth of the whole in alloy: and from the reign of king Charles the second, when guineas were first coined, all our gold money has this alloy. In the reign of Henry the eighth and Edward the sixth we had both gold and silver coins made of much baser metal than the present standard, and varied with such irregularity, that in one of the coinages of Edward the sixth in exchanging gold coin for silver a man would not receive above double the weight of his gold in pure silver.

Copper by a mixture of tin makes the metal for bells and for what are called brass cannon. For bells one part of tin for four of copper, but for cannon not above half so much tin is used. Bells are rendered yet more sonorous by the ad-

dition of a little spelter. This composition is made use of in the fine bells of striking-watches.

It is remarkable, that tin, though itself a soft metal, greatly adds to the sonorous quality of other metals. Tin mixt with twice its weight of lead composes the metal for organ-pipes.

Lead mixt with copper in the proportion of one part of lead to four of copper makes, what is called pot-metal, useful in coarse works. This metal is harder than copper, or even brass.

Copper requires a great heat to keep it intirely fluid, so that, if it be melted ever so perfectly, it very soon congeals, after it is out of the furnace. For this reason it is scarce possible to cast any great work of copper alone, especially if the work has many inequalities in it. Statuaries therefore never attempt to cast statues in pure copper; but use always a more fluxile metal by compounding the copper with some other metal. Either brass, tin or lead will answer this end; and these compositions are in general called by the name of bronze.

Brass with spelter is the composition of Bath-metal.

Nine parts or more of tin with one of the regulus of antimony composes pewter.

Metals are also mixt to make folders, wherewith to join other metals together. It is required in folders, that they melt sooner than the metal to be soldered, and that they approach as near as may be to the metal soldered in hardness, and colour.

Iron is usually soldered with brass alone.

Lead is soldered with a mixture of two parts lead with one of tin. The folder of the tin-men is equal parts of lead and tin; the other not approaching near enough to the tin in colour.

One part of brass, and two of spelter make that, which is usually called spelter-folder, wherewith iron, brass and copper may be soldered together. This is the folder used by the braziers and copper-smiths. This folder is improved, by adding to each ounce of it one penny-weight of silver. This folder melts not without a considerable degree of heat. Therefore this folder cannot be used, where it is inconvenient to heat the work red-hot. In this case therefore copper and brass are soldered with pewter.

Two parts of silver and one of brass will melt sooner than either silver or brass, and therefore is used in soldering either of these metals. This is usually called silver-folder. This folder is

used to folder pieces of brass together, by those who make the finer kind of works in brass.

Both silver and gold melt sooner by having more alloy, and therefore by a folder of such a composition may be foldered. The nearer the folder comes in fineness to the metal, the greater care is required, that the work melt not in foldering: but the nearer will the folder approach to the work in colour.

The pewterers use a kind of folder made with two parts of tin and one of bismuth. This composition melts with the least heat of any of the folders.

But in foldering some artifice is necessary to make the folder and metals adhere.

All the metals except silver and gold upon melting, or before, are covered over with dross; and all the folders have some of these metals in them. This dross hinders the folder and metal from uniting; for I have already observed, that metals unite easily with each other, but not with their dross. Therefore it is necessary, that this dross be removed. This is not performed in all foldering by the same materials.

The plumbers effect this with grease. They first grease their lead, where they design the folder to adhere, then lay the folder on and melt it
with

with a hot iron. What dross, the melting generates, unites with the grease and flows away from off the melted metal. The glaziers and tin-men use rosin in powder for the same purpose; for all inflammable substances, that will melt, are equally conducive to this use. I have before observed, that the drosses of metals, when vitrified, separate clean from the metal; but before, while less perfectly calcined they adhere a little. Now these substances, that in a proper degree of heat, will reduce the calxes of metals back to their metallic form, in a less heat, will so join with the calx as to cause it to separate clean from the metal.

Always in foldering the metals must be made very bright, where the folder is to take hold of them: for any dirt or soil will prevent the adhesion.

Analagous to this method of foldering is that, whereby iron plates are covered over with tin; for making the tin ware so much in use.

In Germany these plates are hammered out under a large hammer. The hammer is a very heavy one, lifted by a water-wheel, and the plates are not brought under it single, but a great number together; and that each may receive an equal battering from the hammer, they

are continually shifted among one another by the workman, that holds them to the hammer, whereby each in its turn only receives the immediate blow of the hammer. In England we roll them out, when red hot, by a mill between iron rollers.

These plates are scoured bright with sand, being first soakt in a weak kind of vinegar, then are dipt into a pot of melted tin covered over with fat; so that the plate passes through the fat in going into the tin. When the plate is drawn up a thin covering of tin adheres to it. The fat is fittest for the purpose, when it has been first fried black, whereby a part of its watry humidity has been evaporated.

Copper and brass are covered over with tin by the help of another material, sal ammoniac, which also contains some portion of an inflammable substance, for thrown on nitre it flames.

The copper or brass being made hot enough to melt tin laid upon it, is strewed over with sal ammoniac, and the melted tin rubbed about the plate. The sal ammoniac licks up the dross of the tin, and leaves the tin to flow freely upon the metal. The same material is used, when copper or brass is foldered with pewter. The work is first washed with a solution of sal ammoniac

niac in water; then heated just hot enough to melt the pewter, and the pewter applied to the joint to be soldered.

In foldering, that requires a greater heat, borax is the material used. In this case the borax by a great heat melting into a kind of glass unites with the dross of the folder or the other metals, and separates it clean from the metal.

Silver and gold produce no dross in our fires; gold therefore can be joined to silver with heat only without any medium. Thus silver bars are gilt, before they are drawn into wire. Thin leaves of gold are spread out upon a table, the bar of silver made pretty hot is rolled upon them, and they adhere. Then the bar is heated red hot, and rubbed, till it is cold, with smooth stones. After this the gold adheres so firmly, that it never leaves the surface of the silver, though the bar above an inch thick is drawn out into an exceeding small wire. Dr. Halley has computed, that the gilding will be thus extended upon silver wire, till it be less than one-hundred-thousandth part of an inch thick.

Among the mixtures made with metals must be reckoned the amalgamating them with quicksilver. This metal will unite itself with all the rest, except iron; though not very freely with copper. Quicksilver will unite with so much of

the other metal, as to form a soft consistence between the fluidity of quicksilver and the solidity of the other metal. All these compositions are called amalgamas.

The facility, wherewith quicksilver unites with lead, has given occasion to the adulterating it with that metal. To make an amalgama expeditiously it is only necessary to heat the quicksilver, and either melt the other metal, or at least make it red-hot; and then to pour on the quicksilver. But the most convenient method for gold, silver, and copper is to dissolve the metals in an acid spirit, and then precipitate them again by another metal capable of producing that effect. By this means the metal will be reduced into more subtle parts than by any other method whatever; and quicksilver will then very readily unite itself with the other metal.

However quicksilver will unite itself, though not so expeditiously, with lead, tin, gold, or silver, if any of those metals are put into it cold. Looking-glasses are covered over with an amalgama of quick-silver and tin. A thin sheet of tin is first spread out upon a flat marble laid to a true level. These sheets of tin are hammered out under a heavy hammer, as the iron plates are hammered out for tinning. They are not thicker
than

than the thickest sort of whited brown paper. Upon such a sheet of tin spread out they pour a little quicksilver and with a cloth and hare's foot spread it equally over the tin. Then they pour more quicksilver on, and with an even hand slide the glass over it. As soon as this is done, they set two or three brass weights about the glass to keep it steady, and then incline the marble for all the useless quicksilver to run off. In the last place the glass is covered over with weights, of about seven pounds a-piece, as close as they can stand by each other. In three hours time the foil adheres firmly to the glass.

I have a little before observed, that silver might be gilt by barely laying on leaf-gold upon it and rubbing it hard on, the silver being made red-hot. In works, where such heating and forcible rubbing are not proper, the gilding is performed with an amalgama of gold and quicksilver; this being spread over the silver, and then the silver heated in a small degree, that the quicksilver evaporate, the gold will remain behind, and with a burnisher is rubbed smooth. A burnisher is only a piece of steel set to the temper fit for the hardest edge-tool, and polished very smooth.

Thus

Thus are gilt both silver and brass. There is another artifice of giving brass a golden colour, called lackering. This is done by passing over the brass, when a little warm, a brush dipt in a solution of gum lac in spirit of wine tinged by some material that shall give it the desired colour.

L E C.

LECTURE XXIV.

THE CONCLUSION.

WE have now gone through the operations of chemistry upon the several subjects, that come under its cognizance, by which we may observe the great extent of the art. It takes under consideration all parts of the creation, that are within our reach to operate upon.

We may farther learn this from the whole, that the powers of nature, by which its operations are performed in the small parts of matter, are very few and simple.

The first operations of chemistry pursue the analysis of bodies, till the most compound are reduced to five principles, water, spirit, oil, salts, and earth. A more careful examination has indeed discovered a sixth, a vapour similar to the air we breathe. But most of these are found to be compound substances, and may be reduced to a smaller number of principles.

The

The spirit and salt are only some active power joined to one of the other principles. Salts are only some active power joined with an earth; spirits some active power joined with water. This power we have found, when joined with water only, to appear under the form of an acid. But the vinous spirit is here to be excepted. This spirit partakes more of the nature of an oil.

Oils part visibly into earth, and spirit or water. At the same time they lose a portion of air, and cease to be inflammable. The air therefore is either the principle, which renders them inflammable, or separates them from the rest by the expulsion of the inflammable principle. At the most therefore oils are divisible into four principles, three of which are the same, as are found in other substances.

There are other substances, in which this principle of inflammability is found, that are some of them no less, others more simple than oils. All vegetable and animal substances are reduced by distillation to a black coal, wherein this inflammable substance is united with earth and a salt, or with earth alone. The vinous spirit seems to be this inflammable substance united with water; for if it be burnt slowly
under

under a bell, as sulphur is burnt to obtain its acid spirit, a considerable quantity of water will be collected, and no inflammable spirit. With the small heat of distillation scarce any air separates from it. But if it be boiled, air separates. This is most commodiously tried by a glass in the form of a thermometer; for if the spirit in the ball be caused to boil, there is always found upon its cooling a bubble of air in the ball.

This inflammable substance is in bodies, that do not burn. We have shewn it beyond contradiction to be in metals. And, if we consider Mr. Boyle's experiment upon water, whereby he reduced it to a dry earth, (that is, calcined it like a metal) we cannot doubt, but that water is held fluid by the same principle, as renders metals fluxible with a due degree of heat. One of them, quicksilver, remains fluid with less heat than will keep water so, and requires a gentle heat to calcine it, as water does. I am informed, that water has been calcined in a close vessel, by standing a long time in a moderate heat, much after the manner, as quicksilver is calcined, only with this difference, that no access of air at all must be allowed the water, lest it should evaporate. Mr. Boyle's method
of

of converting water into earth is by repeated distillations.

Upon these considerations we may conclude, that the bulk of all bodies consists of particles of matter, in different bodies diversely figured and composed, which of themselves are unactive. These we may call terrestrious or earthy parts. These appear to be actuated by two principles at most, the acid, and the inflammable principle. This last we shall call sulphur; as I apprehend this to be the meaning of the word, when used with propriety in its philosophical sense, though no word has been more loosely used by writers than this.

We find the presence of this sulphur necessary to the form of bodies. Metals, when divested of a due portion of it by calcination, lose their metallic form; animal and vegetable substances, till deprived of this principle retain their organic structure; but no longer.

Farther, sir Isaac Newton, in his treatise of Optics, gives reasons for concluding, that bodies act more or less upon light in refracting and reflecting it, in proportion as they abound with sulphur. Sulphureous bodies also soonest grow hot. Now as heat dilates bodies, and at length separates their parts, dissipating the body in smoke,

smoke, we may consider sulphur as the author of the repelling force found in bodies; for this repelling force depends upon heat, which operates most immediately upon the sulphur of bodies, as we have just now said. Even the expansion of the air depends upon its heat.

Thus sulphur by the mediation of heat is the author of the repulsive force seen in nature, which is one cause of the changes, bodies undergo in the course of things: the other is the acid principle. The particular power of this seems to be the uniting other parts of matter with water; whereby the component parts of bodies are transferred from place to place, and the whole œconomy of nature in the reciprocal resolution and renovation of all sublunary beings is throughout the course of time carried on.

These are the general deductions to be drawn from the operations of chemistry.

I shall now put a conclusion to this Course by some particular remarks, that have not yet fallen in our way.

In the course of these lectures we have had occasion to take notice of some changes made in the taste, smell, and colour of bodies by the means of spirits and salts. Silver dissolved in spirit of nitre acquires an extreme bitter taste, lead a sweet one,

one, whether dissolved in spirit of nitre or in vinegar. Sulphur dissolved in water either by the help of lime or of an alkaline salt, upon the affusion of an acid spirit sends forth at once a smell extremely fetid resembling that of rotten eggs; and changes from its red tincture to a white one.

But what relates to colours has not been yet considered so fully as the subject deserves. The painters, dyers, and the workers in glass have received great assistance in their colours from the art of chemistry.

Glass is coloured chiefly by metals or metal-line substances, these enduring the strongest fires. It is coloured yellow indeed by a vegetable substance, bran. But this glass must not remain very long in the fire. It is tinged blue by the mineral substance before described with arsenic called zaffora or zaphor, of a sky-colour by calcined copper, green by calcined iron, and red by gold dissolved in aqua regia. There must be put a little common salt into the glass along with the gold prepared as above, otherwise they will not unite. There is a remarkable incident occurs in working this colour. That the glass, when first taken up and blown, appears transparent like other glass, but by being often put into the furnace and drawn out, the tinging particles

ticles gradually assemble together, and give a colour to the glass. Silver is of no use in this art. It gives glass a yellow colour indeed but of a disagreeable hue. Glass is tintured black by magnesia, the substance wherewith they take off its green colour. This substance in a small quantity only removes the green hue natural to glass; but in a larger proportion dyes it purple, and if this purple is very intense, it appears black.

The painters owe to white lead the ground of their art. It is their white. This calcined for a time turns yellow and is called masticot. They have been of late indebted to chemistry for a very necessary colour the Prussian blue. Their best black is the coal of an animal substance calcined. Ivory-black is ivory calcined.

The dyers also make a very general use of alum and tartar; therefore the reason for the fundamental work of their art is to be taken from chemistry. Their colours are chiefly extracted from vegetables, disposed to tinge water of each colour. And their tinctures are prepared without any particular artifice except in woad. This vegetable after it is gathered, is moistened and pressed together, that it may heat, then dried, and the same process repeated two or three times. An infusion of this by a mixture of

lime will slowly ferment. During the fermentation it dyes a blue colour. Alone it makes only a sky-blue, but with a proper addition of indico, the inspissated juice of a similar plant, the colour may be deepened to any degree. The cloth comes green out of the liquor; but by the contact of the air turns immediately blue. The finest scarlet is dyed with cochineal, now supposed to be an animal substance. To dye with this colour requires some acid spirit, as I have take notice before. But it must first have corroded tin, else it will destroy the cloth. There is also another circumstance necessary. The dying must be performed in a tin or pewter vessel. Should one of copper or iron be made use of, the spirit would quit the tin and act on the vessel, and during that action would also corrode the cloth.

The dyers have no material of a black tint, wherewith to dye that colour. They dye that colour with copperas or the like ferrugineous substance, and with an astringent vegetable, usually with galls. For an infusion of galls, grana-te-bark, or any vegetable astringent in water added to a solution of copperas becomes immediately black. Common writing-ink is made by this means with the addition of a little gum to make it more stable upon the paper.

By

By this effect of vegetable astringents upon ferrugineous substances, medicinal waters are usually tried, how far they are to be esteemed of the chalybeate kind.

It is from the art of chemistry that we must learn the nature of mineral waters.

Waters, as they arise from the earth, are generally more or less tinged with the vitriolic acid, which I have before observed to abound in the bowels of the earth. This acid is that, which hinders soap from dissolving in spring-waters: for all acids produce this effect in water. The water, which has ran long in the channel of a river, has met with substances, that imbibe this acid. In their passage under ground they also find some portion of calcarious and other substances, whereon the acid will operate: and as I observed formerly, that this acid acts stronger upon the alkaline salts, than on any other substances; so we may find, those salts generally make a precipitation from spring-waters. What precipitates is of the calcarious kind. The same incrustates vessels, wherein it is boiled. That crust well calcined heats and smokes upon the affusion of water like common lime.

If these waters find any metallic parts, that the acid will take up, the waters become medicinal. Some express great jealousies about these

waters, lest they should contain lead, arsenical parts, or the like pernicious ingredients; but of all metallic substances, iron and copper only will be united with water by this acid. So that mineral waters can contain no metallic substances except iron or copper. Iron is the most common ingredient. Where there is copper the water has an emetic quality. Iron in these waters is discovered by the means, I mentioned before.

The greater part of these metallic waters have a sprightly spirituous taste, and sparkle upon pouring out. It has much perplexed the enquirers into these waters to discover the original of this spirituousness. If the water stands open, this quality is soon lost. But if when taken from the spring it be immediately confined close, it preserves this spirit a great while, unless it chance to break the vessel containing it.

There are waters furnished very eminently with this active spirit, that have no metallic parts in them. They do not therefore owe it to them. All these spirituous waters shew signs of being impregnated with alkaline parts. As I observed, that waters in the earth not only are charged with an acid, but meet also with calcareous parts, whereon the acid will act; these waters rise out of the earth, before the fermentation

tion is over, and the spirit found in them is no other, than what arises in fermentations. If the water is forcibly confined, that this spirituous vapour cannot expand itself, the fermentation is restrained, and the water kept in this fermentable condition a great while.

If these waters contain metallic parts the fermentation gradually deprives them of the acid, that kept them suspended: for this reason, when chalybeate waters have lost their spirit, the iron parts are found at the bottom in the form of ocher.

When the fermentation has been strong, the waters rise warm.

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